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ABSTRACT

A model was developed for teaching beginning shorthand through the use of computer-assisted instruction (CAI). The model was based on the supposition that incorrect responses decrease the efficiency of the learning process. A response not completed within the amount of time required for a correct response was predicted to be incorrect. In the first phase of the experiment, the median correct-response latency for each stimulus for each subject was ascertained and stored in the computer. In the second phase, each experimental subject's response latencies were monitored and compared to median correct-response latencies. If the subject's response latency exceeded the median correct-response latency by one second, the request for a response was replaced by a prompt consisting of the correct response before proceeding to the next stimulus. No attempt was made to intercept incorrect responses for control subjects. Analysis of data indicated that the subjects assigned to the interception method required more time to reach criterion and made fewer incorrect responses than the control subjects. Analysis of the subjects' retention patterns over a four-week period showed no significant differences between the experimental and control groups. (JY)

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COMPUTER ASSISTED INSTRUCTION LABORATORY

COLLEGE OF EDUCATION · CHAMBERS BUILDING

THE PENNSYLVANIA STATE UNIVERSITY · UNIVERSITY PARK, PA.

FINAL REPORT

Project No. 0B015
Grant No. OEG–2–700019(509)

Karl G. Borman

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ABSTRACT

The learning theories of Guthrie, Voeks, Sheffield, and Skinner, and the research literature related to proactive and retroactive inhibition were used to formulate a model for the teaching of beginning shorthand through the use of computer-assisted instruction. The model was based on the proposition that the prevention of errors would increase the efficiency of the learning process. Response latency data were used for the prediction of incorrect responses. Each response not completed within the amount of time required for a correct response was predicted to be incorrect, then "intercepted." Following the prediction of an incorrect response the subject was shown the correct response and prevented from completing the response. The "interception" method of instruction was contrasted with the prompting and confirmation methods of instruction.

Results indicated that the interception method of instruction required more time, a greater number of correct responses, and a lesser number of incorrect responses from the subjects before the criterion of ten successive errorless trials was matched than the other methods of instruction. None of the methods of instruction resulted in significant gains in retention measured over four seven-day intervals.

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TABLE OF CONTENTS

		Page
ACKNOWLEDGMENTS		ii
LIST OF TABLES		v
LIST OF FIGURES		vii
Chapter		
I.	INTRODUCTION	1
II.	DEVELOPMENT OF THE MODEL	6
	LEARNING THEORY	6
	RETROACTIVE INHIBITION	11
	PROACTIVE INHIBITION	13
	RESPONSE LATENCIES AND ERRORS	15
	CONFIRMATION	19
	PROMPTING	21
	STATEMENT OF THE MODEL	24
III.	PRE-EXPERIMENT: THE DEVELOPMENT OF MATERIALS	26
	DESIGN OF PRE-EXPERIMENT	29
	SUBJECTS	29
	MATERIALS	29
	PRE-EXPERIMENT PROCEDURE	30
	RESULTS	33
	POST HOC VERIFICATION OF ITEM PAIRING	36
IV.	THE EXPERIMENT: TEST OF THE MODEL	46
	SUBJECTS	47
	EXPERIMENTAL DESIGN	47

Chapter Page

PROCEDURE 52

ANTICIPATED RESULTS 57

V. RESULTS 59

TIME-TO-REACH-CRITERION 60

NUMBER OF CORRECT RESPONSES 64

NUMBER OF INCORRECT RESPONSES 67

14-DAY RETENTION 71

28-DAY RETENTION 72

VI. DISCUSSION 76

VII. SUMMARY 83

REFERENCES 89

APPENDIX 93

LIST OF TABLES

Table		Page
1.	Cell Frequencies Obtained by Random Assignment as Generated by the Computer Program (N=23).	33
2.	Mean Median Correct-Response Latencies and Standard Deviations of the Beginning Shorthand Symbols	37
3.	Ranks of the Beginning Shorthand Symbols by Mean Median Correct-Response latencies (N=8)	38
4.	Correspondence of Items in Stimulus Sets A and B. . . .	39
5.	Summary of Multiple Comparisons Computed by Scheffe's S Method for the Second Instruction Session using Time-to-Reach Criterion as the Dependent Variable . .	64
6.	Summary of Multiple Comparisons Computed by Scheffe's S Method for the Second Instruction Session using Number of Correct Responses During Acquisition as the Dependent Variable.	67
7.	Summary of Multiple Comparisons Computed by Scheffe's Method for the Second Instruction Session using Number of Incorrect Responses During Acquisition as the Dependent Variable	70
8.	Summary of Multiple Comparisons Computed by Scheffe's Method for the Sequence-of-Instruction-Methods Treatment Effect using the Number of Correct Responses Obtained at Two Seven-Day Intervals to Stimulus Set B as the Dependent Variable.	73
9.	Summary of Multiple Comparisons Computed by Multiple-T Method for the Sequence-of-Instruction-Methods Treatment Effect using the Number of Correct Responses Obtained at Four Seven-Day Intervals to Stimulus Set A as the Dependent Variable.	74
10.	Analysis of Variance Summary Table Using Time-to-Reach-Criterion During Acquisition as the Dependent Variable.	94
11.	Analysis of Variance Summary Table for Simple Effects During the Second Instruction Session using Time-to-Reach-Criterion as the Dependent Variable.	95

Table		Page
12.	Analysis of Variance Summary Table using Number of Correct Responses During Acquisition as the Dependent Variable.	96
13.	Analysis of Variance Summary Table for Simple Effects During the Second Instruction Session using Number of Correct Responses During Acquisition as the Dependent Variable	97
14.	Analysis of Variance Summary Table using Number of Incorrect Responses During Acquisition as the Dependent Variable.	98
15.	Analysis of Variance Summary Table for Simple Effects During the Second Instruction Session using Number of Incorrect Responses During Acquisition as the Dependent Variable	99
16.	Analysis of Variance Summary Table for Stimulus Set A using Number of Correct Responses as the Dependent Variable.	100
17.	Analysis of Variance Summary Table for Stimulus Set B using Number of Correct Responses as the Dependent Variable.	101
18.	Analysis of Variance Summary Table for Stimulus Set A using Number of Correct Responses as the Dependent Variable.	102
19.	Analysis of Variance Summary Table for Stimulus Set B using Number of Correct Responses as the Dependent Variable.	103

LIST OF FIGURES

Figure		Page
1.	List of Shorthand Symbols used as Stimuli	28
2.	Response Latency Profile for One Subject on One Item.	35
3.	Subject A's Response Latency Profile for Item 28.	41
4.	Subject A's Response Latency Profile for Item 27.	42
5.	Subject B's Response Latency Profile for Item 24.	44
6.	Subject A's Response Latency Profile for Item 22.	45
7.	Experimental Design	49
8.	Lindquist Type I Design used for Analysis of Retention Data.	51
9.	Interactions Between Sequence of Instruction Methods and Instruction Sessions using Time-to-Reach Criterion as the Dependent Variable	62
10.	Interactions Between Sequence of Instruction Methods and Instruction Sessions using the Number of Correct Responses During Acquisition as the Dependent Variable.	66
11.	Interactions Between Sequence of Instruction Methods and Instruction Sessions using the Number of Incorrect Responses During Acquisition as the Dependent Variable.	69

CHAPTER I

INTRODUCTION

The application of the computer to educational tasks has resulted in a variety of instructional strategies never before possible in schools. Computer-assisted instruction has made a reality of the individualization of instruction, a seemingly necessary component for reaching the long-range goal of an adaptive education for every learner. (Mitzel, 1970) Until the time that computer-assisted instruction systems were available for schools, the individualization of instruction was accomplished by having each student work on his own project, whether it be a programed textbook, a teaching machine, an audio recording or some other medium, in an isolated location. Self pacing has been the defining characteristic of individualized instruction. All of the students use the same teaching machine programs, workbooks and programed textbooks.

Computer-assisted instruction also allows a student to learn at his own pace. Although all students use the same computer-assisted instruction program, each student's path through the instruction program is different. Each student's path is determined by the computer based on the student's needs, abilities, and past performance.

Traditionally, each student's needs are met only to the extent that they coincide with the needs of the mythical "average" student in the classroom. The classroom teacher determines the nature of the instructional sequences based on the progress of the "average" student. When the class average on a test equals or exceeds a previously established criterion for a given objective, the whole class then moves on to

the next objective. No provisions are made for the student(s) whose performance is markedly above or below the class average. The student's need for additional practice or for information presented in a different format are not satisfied. Instead, the slower student is exposed to more advanced material even though he has not mastered the elementary material.

Similarly, the "fast" student in the traditional class had probably met the established criterion at some earlier point in time and was then ready to undertake advanced material. The faster student's need for advanced material was not met until the average student's need for advanced material became evident. Instead, the faster student was forced to wait for the average student to reach criterion.

Each student has his own set of needs which must be met to enable the student to reach criterion in the most efficient manner. The best method of instruction for one student is not the best method of instruction for another. It is virtually impossible for the classroom teacher to be aware of and meet the needs of all the students all of the time. The best that can be hoped is for the classroom teacher to meet the most common needs of the majority of the students.

The computer, because of its capability to analyze vast amounts of data in a very short time, is able to continually monitor and analyze each student's performance and alter the instruction sequence to meet each individual's needs. The sequence of events for a given student is based on that student's performance record instead of being based on the progress of the average student.

The student's performance record, rather than the average student's performance, is used by the computer to determine when each

student should progress to the next objective. The criterion a student must obtain on each objective before that student is allowed to proceed to the next objective is stored in the computer. The computer can then be programmed to present instructional material to the student and continually analyze the student's performance. Instructional material is presented to the student until his score equals or exceeds the criterion. This strategy guarantees that each student has mastered the prerequisite material before proceeding to more advanced material.

The strategy outlined above is appropriate for the teaching of beginning shorthand. Shorthand instructors have been constantly reminded of the necessity for establishing a firm background in the recognition of the symbols comprising the shorthand alphabet. The authors of the Instructor's Handbook for Gregg Shorthand for Colleges, Leslie, Zoubek and Hosler (1965) state:

> . . . The shorthand alphabet is the most important part of the teaching of shorthand. When the learner knows the shorthand alphabet perfectly, other gaps in his knowledge are not likely to prove a serious handicap. . . . (p. 16)

Previously, Leslie (1953) has observed:

> . . . The sentence and the paragraph are the foundations of office dictation, and the basis of good sentence writing in shorthand is the word. Do not, therefore, neglect the individual shorthand symbols and the individual words into which the symbols may be combined. . . . (p. 459)

It was the purpose of this study to develop and test a model for the teaching of beginning shorthand utilizing the potential advantages gained by the use of computer-assisted instruction.

The model was based on the premise that incorrect responses are predictable and decrease the efficiency of the learning process. The prediction of incorrect responses was based on the conclusion, derived

from an examination of research literature related to response latency data, that latencies of incorrect responses were reliably longer than latencies of correct responses. Once a correct-response latency was determined for a student, latencies of incompleted responses were compared to the known correct-response latency. When the subject required more time to make a response than the amount of time required for a correct response, the prediction was made that the completed response would be incorrect. Since the prediction was made before the completion of the response, action was taken to prevent the occurrence of the response based on the premise that errors inhibit the learning process. The occurrence of an error necessitated the administration of an additional trial during which the correct response is given the opportunity to occur and become conditioned to the stimulus. The additional trials were thought to be unnecessary if incorrect responses were prevented from occurring.

A capability unique to the IBM 1500 Computer-Assisted Instruction System was utilized to implement and test the model. The IBM 1500 Computer-Assisted Instruction System[1] measures to the nearest one-tenth of a second the time required for a student's response. This capability, together with the computer's computational ability, permitted the collection of data defining each individual's correct response latency while the student was working at a student station. These data were used during later instruction to alter the sequence of instruction based on the probability of the occurrence of an incorrect response.

---

[1]Hereafter referred to as the computer or the system.

The system is also capable of controlling to one-tenth of a second, the amount of time allotted for a student's response. The student's failure to respond within a given period of time was detected by the computer causing the alteration of the instructional sequence. A period of time equal to the student's correct-response latency was allotted for each response. Responses which were not completed within the allotted time period were prevented from occurring.

Thirty basic shorthand symbols were programmed to appear on the cathode ray tube, a device similar to the screen of a small television set. Four methods of instruction, one of which was based on the model, were programmed into the computer. Each instruction method had a criterion of 10 consecutive errorless trials. The student typed what he thought to be the correct name of each symbol on a typewriter-like keyboard associated with the student station. The computer program compared the student's typed answer with the correct answer stored in the computer and used that information to determine the type of material to be presented to the student. Each student's performance record was used to determine the sequence of the material remaining to be presented.

CHAPTER II

DEVELOPMENT OF THE MODEL

Learning Theory

The behaviorist E. R. Guthrie's theory of learning formed the basis for the model used in this study for the teaching of beginning shorthand by means of computer-assisted instruction. His theory as originally conceived was based on observable responses such as muscular movements and glandular secretions. Guthrie's "law of learning" is summarized by two statements:

> . . . A combination of stimuli which has accompanied a movement will, on its recurrence, tend to be followed by that movement. . . . (Guthrie, 1936, p. 261)

> . . . A stimulus pattern gains its full associative strength on the occasion of its first pairing with a response. . . . (Guthrie, 1942, p. 30)

Guthrie's theory predicted that movements made during the presentation of a stimulus will be the response given at the next presentation of the stimulus. Since it was obvious that alternate responses are made in the presence of a seemingly identical stimulus, Guthrie argued that the true stimulus was not the stimulus as measured, but the stimuli produced by movements in the organism at the time the measured stimulus was presented.

Experiments by Guthrie and Horton (1946) validated Guthrie's theory. During each experiment the authors placed a cat in a puzzle box and took photographs of the cat at the time the animal activated an escape mechanism. Analysis of the photographs showed that, "In numerous instances the successful movement was one that had been

observed previously." (p. 38) In those instances where the animal failed to repeat the movements that lead to escape, the authors gave the following explanation:

> . . . In a number of cases the reason for the difference appeared to be fairly obvious. A noise in the room, a fly on the wall of the box, a movement by one of the spectators would be responded to by the cat and the sequence of movements interrupted, sometimes not to be resumed. . . . (p. 38)

The authors concluded from the observations of the series of experiments:

> . . . that the prediction of what an animal would do at any moment is most securely based on a record of what the animal was observed to do in that situation on its last occurrence. . . . (p. 42)

Virginia Voeks, one of Guthrie's students, extended his theory with the formulation of four postulates based on her collection of Guthrie's statements. Her four postulates are as follows:

Postulate 1: Principle of Association

a) Any stimulus pattern which once accompanies a response, and/or immediately precedes it (by 1/2 seconds or less), becomes a full strength direct cue for that response. b) This is the only way in which stimulus-patterns not now cues for a particular response can become direct cues for that response. (Voeks, 1950, p. 342)

Postulate 2: Principle of Postremity

a) A stimulus which has accompanied or immediately preceded two or more incompatible responses is a conditioned stimulus for only the last response made while that stimulus was present. b) This is the only way in which a stimulus, now a cue for a particular response, can cease being a cue for that response. (Voeks, 1950, p. 344)

Postulate 3: Principle of Response Probability

The probability of any particular response's occurring (P) at some specified time is an increasing monotonic

> function (x) of the proportion (N) of the stimuli present which are at the same time cues for that response ($P = N^x$). (Voeks, 1950, p. 348)

> Postulate 4: Principle of Dynamic Situations
>
> The stimulus-pattern of a situation is not static but from time to time is modified, due to such changes as result from the subject's making a response, accumulation of fatigue products, visceral changes and other internal processes of the subject, introduction of controlled or uncontrolled variation in the stimuli present. (Voeks, 1950, p. 350)

Based on these postulates it appeared that any response, whether it be correct or incorrect becomes conditioned to a stimulus immediately after the simultaneous occurrence of the stimulus and response (Postulate 1). Postulate 4 allowed for a new or unique response to be made to a given stimulus, but once that response has been made, it replaced the previous response and became the conditioned response. In the event other responses were made, as allowed by Postulate 4, Postulate 2 specified that that response is the response that will be given upon the next presentation of the stimulus.

A further extension to Guthrie's theory, of importance to this study, was made by Sheffield, an undergraduate student of Guthrie's. Sheffield added the assumption that responses which do not have a motor component exist and can be conditioned to a stimulus. These responses were called perceptual responses. Sheffield (1961) stated:

> . . . The position taken here is that what is usually called "perception" refers to cases in which the immediate sensory stimulation is not only eliciting its innate sensory responses, but is also eliciting other sensory responses which have been conditioned to the immediate stimulation in past experience. . . . (p. 15)

According to Sheffield, perceptual responses are related to symbolic responses. A symbol, "is an arbitrarily determined stimulus which has

been conditioned to the perceptual responses appropriate to a stimulus object." (p. 22) The name of a person, then, is a symbolic response which:

> . . . by virtue of practice at hearing, seeing, speaking, etc., the name in connection with the person, it becomes capable of reinterpreting the perceptual response learned to the person as a stimulus object. . . . (p. 22)

Guthrie's "law of learning" and the extensions of the theory set forth by Voeks and Sheffield were applicable to shorthand instruction. The last symbolic response (Sheffield) made to a stimulus (a shorthand symbol) will be the response that will be given following the next presentation of the stimulus (Guthrie and Voeks). If the response elicited by the stimulus was the desired response, the objectives have been obtained. However, if the last response given to a stimulus was an incorrect response, provisions must be made as indicated by Voeks' fourth postulate for an alternate response to be made since it is desired that the correct response remain associated with the stimulus. Bugleski (1964) in summarizing these principles, formulated a practical application of Guthrie's theory:

> . . . Never allow a learner to leave a learning situation with a wrong answer or incorrect response. Let the last response that occurs be correct. . . . (p. 104)

B. F. Skinner maintained that errors do not contribute to the learning process. In denouncing the use of multiple-choice material in favor of constructed responses, Skinner (1958) stated:

> . . . effective multiple choice material must contain plausible wrong responses which are out of place in the delicate process of "shaping" behavior because they strengthen unwanted forms. . . . (p. 970)

Bugleski (1964) attributed Skinner with believing that learners should be controlled so they almost always do the right thing, since errors only delay arrival at the goal. (p. 210)

Kaess and Zeaman (1960) conducted an experiment, the results of which verified Skinner's statement. Kaess and Zeaman (1960) used a Pressey-type punchboard and controlled the number of errors a subject could make by controlling the number of alternatives presented as possible responses to multiple-choice questions. Six experimental groups were formed by varying the number of options per question presented to each group on the first trial. Group one answered multiple-choice questions containing only one "option," the correct answer. Group two had to choose an answer from among two options, etc. and group five had to choose an answer from among five options per question. A sixth group also had five options per question, but the subjects were not required to answer each question correctly before going on to the next question as the other experimental groups were required to do. Five options were presented to each group during trials two through five. The results indicated that the number of options presented to the subjects on the first trial was directly related to the number of errors made on the following trials even though the subject had to choose the correct answer before moving on to the next item. Kaess and Zeaman (1960) concluded:

> . . . The assumption of Porter and Skinner that incorrect items interfere with the acquisition of correct responses is supported by the results of Exp. 1. . . . (p. 16)

Retroactive Inhibition

The high degree of similarity among the beginning shorthand symbols, e.g., — and —— representing n and m respectively, or ⟋ , ⟋ , and ⟋ representing s, f, and v, subject the list of shorthand symbols to various degrees of retroactive and proactive inhibition. McGeoch (1952) defined the term "retroactive inhibition" based on the usage of Müller and Pilzecker (1900):

> . . . The term refers to a decrement in retention resulting from activity, usually a learning activity, interpolated between an original learning and a later measurement of retention. The expression is not, however, to be taken literally. It is not retroactive in the sense that interpolated activities work backward in time. The term "retroactive" is an as if modifier, meaning that it is as if this occurred. . . . (McGeoch, 1952, p. 404)

Britt (1935), in reviewing all of the studies dealing with retroactive inhibition through December, 1934, made the following conclusions: the phenomenon of retroactive inhibition within a series has been demonstrated; learning by both adults and children is subject to retroactive inhibition; both verbal and motor materials and sense and nonsense materials are subject to retroactive inhibition. (Britt, 1935, pp. 426-427)

The series of beginning shorthand symbols being learned by adults is probably initially perceived as nonsense material. The shorthand alphabet becomes a prime candidate for retroactive inhibition effects.

Cheng (1929) used consonant-vowel-consonant or CVC trigrams to test the effects of similarity of stimulus items on retroactive inhibition. During his first experiment 10 CVC trigrams were used for the initial learning task. The interpolated learning task was varied along

a similarity continuum. Various numbers and combinations of letters were held constant for the interpolated learning task. For example, in one of the experimental learning conditions, the first two characters of the interpolated learning task were the same as the first two characters of the original learning task. In another learning task, only the first letter was common to both learning tasks.

Cheng, after conducting a second experiment using 12 syllables and a subset of the experimental conditions, concluded that all of the interpolated conditions exerted some degree of retroactive inhibition. The effect varied with the experiment and the method of measurement. He further concluded that using the method of recall, the retroactive effect first rises then decreases as the degree of similarity increases from zero to identity.

Watson (1938) required his subjects to sort decks of cards into 16 patterns. The number of similar items in the interpolated learning task varied from four to 12. He found that when the interpolated learning task and the original learning task were very similar, the percentage of retroactive inhibition was very low. However, as the amount of similarity decreased, the percentage of retroactive inhibition increased. Similar findings have been reported by Dreis (1933) and Kennelly (1941).

Osgood (1949) proposed a model to predict the amount of positive transfer or the amount of interference that would occur as a result of various combinations of stimulus and response similarities. Osgood predicted that maximum positive transfer would occur when the stimulus elements and the response elements were identical to those used in the original learning task. Similar stimuli and identical

responses would result in a lesser amount of positive transfer. Pairing similar stimuli and neutral or opposite responses, as in the case of learning the beginning shorthand alphabet, resulted in negative transfer, or retroactive inhibition of the original task.

The concept of retroactive inhibition provided further argument to support the hypothesis that incorrect responses hinder the learning process. An incorrect response or an identical response, as in the case where a previously learned response is given to a similar but not identical stimulus, is easily conditioned to the stimulus because of positive transfer according to Osgood's model. Guthrie's theory indicated that conditions must then be created for an alternative response to be given so that the final response, the correct response, remains conditioned to the stimulus. The execution of an additional trial would be required in order for the correct response to become conditioned to the stimulus. Ordinarily, learning a neutral or opposite response to a similar stimulus would result in retroactive inhibition.

Provisions must be made in the teaching of shorthand to continually monitor those stimulus-response pairs that were previously learned so that the effects of retroactive inhibition can be detected and appropriate remedial action taken.

Proactive Inhibition

Proactive inhibition is that condition where a previously established habit has a negative effect upon the establishment of a new

habit. (McGeoch, 1952, p. 394) The degree of stimulus similarity was one variable of importance to the current study, that has been investigated.

Melton and Von Lackum (1941) formed three experimental groups in their study of proactive inhibition. The first group, the control group, received five trials on a list of 10 CCC trigrams. After resting for 20 minutes, the subjects were required to relearn the same list. The remaining groups received five trials learning a list of 10 CCC trigrams followed by a one minute rest period. Following the rest period, one group received five trials on a list of ten CCC trigrams composed of the same nine consonants. The assumption was made that the second list was similar to the first list. The third group received five trials on a list of 10 CCC trigrams composed of nine different consonants following the rest period. This list was assumed to contain dissimilar material. Following a 20 minute rest period, both groups relearned the second list--the list learned prior to the 20-minute rest break. Based on the results of their study, Melton and Von Lackum (1941) made the following generalization:

> . . . The amount of inhibition of both lists is greater when the two lists are similar than when the two lists are dissimilar. The difference is reflected in the recall scores, the trials required for relearning to mastery . . . When the lists are dissimilar, the inhibition disappears very early during the relearning process. . . . (p. 173)

Melton and Von Lackum (1941) venture the interpretation that:

> . . . the proactive inhibition of the recall and relearning of the interpolated list is a result only of the competition of the original responses at the time of attempted recall and relearning of the interpolated responses. . . . (p. 173)

Underwood (1944) required his subjects to learn 0, 2, 4, or 6 lists of paired-adjectives, each list consisting of 10 pairs of two-syllable adjectives, all having the same stimulus, prior to learning a common list. The results showed that the greatest amounts of inhibition occurred on lists 2, 3, 5, and 6 with a decrease on list 4. The decrease on the fourth list was not reliable. Underwood (1944) concluded:

> . . . The data show conclusively that the amount of positive transfer which eventually accrues in the successive lists is directly related to the number of prior lists learned. . . . (p. 135)

In a 1957 article, Underwood reviewed a number of studies which indicated that forgetting was not produced by tasks learned outside the laboratory following the study, but from tasks learned previously in the laboratory.

The evidence on proactive inhibition suggested that early responses made to similar stimuli, such as exist in the beginning shorthand alphabet, compete with the response to be associated with the new stimulus. The competition of responses has an inhibiting effect on the learner's attempt to learn the correct association. Upon detection of this condition the learner should be given the correct response, thus eliminating the inhibiting effects and increasing the efficiency of the learning process.

Response Latencies and Errors

A small number of paired-associate studies investigated the relationship between response latencies and correct or incorrect responses. Millward (1964) conducted a modified paired-associate learning experiment in which the subjects had to learn which of two

buttons was the correct response to each of 12 two-digit numbers between 12 and 88. The problem was run for 20 trials and took about 45 minutes. No significant differences were found when the average latencies of the trials that were correct and prior to the last error were compared to the average latencies of the trials that were incorrect and prior to the last error. However, the trend existed that on 14 of 18 trials, the response latencies for incorrect responses were higher than the response latencies for correct responses.

Suppes, Groen, and Schlag-Rey (1966) also investigated the relationship of response latencies to correct and incorrect responses and arrived at a similar conclusion. Suppes et. al. (1966) required subjects (N=40) to learn which of three keys was the correct response to each of 12 three-letter syllables. Two sessions were conducted a week apart, each session consisting of 300 trials. Again the results showed, "no consistent evidence of a difference between mean error latency and mean success latency prior to the last error." (p. 122) As in the case of Millward's (1964) study, the tendency for incorrect responses to have higher response latencies than correct responses, was present.

Judd and Glaser (1969) replicated the above results. Eight CVC trigrams were used for the stimulus items which the subjects were required to associate with one of 2, 4, or 8 key positions. Each of the trigrams had to be mastered to a criterion of six successive errorless trials. The authors concluded, as did Millward (1964) and Suppes et. al. (1966) that prior to the trial of last error, correct-response latencies did not differ from the latencies of incorrect responses. No

conclusions regarding the trend of incorrect-response latencies being higher than correct-response latencies can be drawn from this experiment since the results varied as a function of key position.

Eimas and Zeaman (1963) conducted a "miniature" experiment in which 12 high association value tri-consonant stimulus symbols were used in conjunction with the numbers from one to 12 which served as the response elements. At the beginning of the experiment, each subject was permitted to study each stimulus-response pair for as long as desired. Following the study period the subject was given two testing trials without reinforcement followed by a second practice trial followed by two more testing trials. The response latencies averaged over subjects and items on each trial indicated that the response latencies of correct responses were reliably lower than the response latencies of the incorrect responses.

Berman and Villwock (1969) using the IBM 1500 Computer-Assisted Instruction System investigated the relationship of response latency to correct or incorrect responses, but not within the framework of a paired-associate learning experiment. Two different types of problems were programmed for use on the system. One of the problems involved counting in bases other than base 10. After the subjects were instructed in counting in non-base 10 number systems, they were shown an example of a base three series and asked to furnish the next number in a base four, base five, or base six series.

Set problems were the second type of problem used in the experiment. In each problem, the subject was shown six geometric figures and told which three figures were part of the set and which three figures were not a part of the set, i.e., which three figures did not contain

a critical feature common to the set members. The subject was shown two alternatives and asked to indicate which of the alternatives was a member of the set.

Analysis of the response latency data for both types of problems using correlated t-tests indicated that response latencies associated with errors were higher than response latencies associated with correct responses. This difference was significant beyond the .005 level.

In summary, Millward (1964), Suppes et. al. (1966) and Judd and Glaser (1969) have shown that a trend exists for response latencies of incorrect responses to be longer than response latencies of correct responses. Eimas and Zeaman (1963) and Berman and Villwock (1969) have shown that response latencies of incorrect responses are reliably longer than response latencies of correct responses. All of the studies, with the exception of Berman and Villwock (1969), suffered from one common fault--they all dealt with grouped data and ingored individual differences in response latency. Shiffrin and Logan (1965) suggested that response speed is learned as a function of practice speed which suggested that some subjects are "fast" responders while other subjects are "slow" responders which has been determined by their past experiences. The "fast" responder would have a short response latency for a correct response while the "slow" responder would have a longer response latency associated with a correct response. The response latency averaged across these two individuals would be at a point midway between their scores. Similarly, the "fast" responder may have a short response latency for an incorrect response while the "slow" responder would have a longer latency for an incorrect response.

The difference between the average latencies of correct and incorrect responses for all subjects would not be as great as if only an individual's data were examined. Individual differences of this type contribute to error variance which lessen the chances of obtaining reliable differences. (Jensen, 1967)

Monitoring an individual's response latency as it occurred and comparing the response latency with the known response latency for a correct response enabled the prediction of an incorrect response when the response latency exceeded the latency of a correct response. Knowledge of an impending error permitted one to take appropriate action to prohibit the occurrence of the error and prevent the error from becoming associated with the stimulus.

Two methods of instruction, confirmation and prompting, appeared to be useful in the development of the model to teach beginning shorthand through the use of computer-assisted instruction.

Confirmation

Confirmation is that procedure in which the subject is shown the stimulus term and required to make a response. Upon completion of the subject's response, the correct response is shown to the subject.

Kaess and Zeaman (1960) conducted an experiment to determine the value of receiving feedback following each response. One experimental group received feedback indicating whether their response was correct or incorrect following each response, by means of a Pressy-type punch board. A second group received no feedback. Successive exposures to the items revealed that the group which did not receive

feedback made significantly more errors during the remainder of the experiment than the group which did receive knowledge of results.

Angell (1949) also used punch boards designed to give immediate feedback, to test the effect of immediate knowledge of results. Angell administered three quizzes to two groups of subjects throughout a course in chemistry. One experimental group used the punch boards and received immediate feedback while the other group had to wait until the next class meeting to receive feedback. The results of the analysis of the final examination scores given at the end of the semester showed that differences between scores on the final examination were in favor of the experimental group that used the punch boards.

Meyer (1960) used eighth graders and programed textbooks to show the superiority of the confirmation mode of instruction. All of the subjects wrote their answers in their programed textbooks. Two groups were permitted to immediately correct their textbooks while the third group had their textbooks corrected by their teacher after the completion of the class. Analysis of post-test scores indicated that those subjects who received immediate confirmation by correcting their own workbooks did better than those who received delayed teacher scoring of the workbooks.

A study conducted by Gilman (1967) examined the effects of various modes of feedback in a computer-assisted instruction setting. Five types of feedback were used: no feedback; knowledge of results feedback; knowledge of correct response feedback; response contingent feedback; and a combination of knowledge of results, knowledge of correct response and response contingent feedback. The results indicated

that those subjects who were told the correct answer following each response, "learned more effectively and performed better than did those who were forced to 'discover' the correct response." (p. 73) The Gilman (1967) study was significant in that it showed the subject the correct answer rather than simply telling him whether he was right or wrong as did the other studies reviewed.

Prompting

Prompting is the method of instruction characterized by the simultaneous presentation of the stimulus and response terms. An overt response by the subject may or may not be required of the subject following the presentation of the stimulus and response. A number of studies have been performed comparing the effectiveness of the prompting and confirmation methods of instruction.

Briggs (1961) compared the prompting mode of instruction, not requiring an overt response, with three other confirmation modes. The single-try confirmation mode showed the subject the correct answer to each question following the subject's response. The multiple-try confirmation mode only informed the subject whether his response was correct or incorrect. Following an incorrect response, the subject had to try again to find the correct response. The last mode, the single-feedback mode, permitted only one response to each stimulus. Following that response, the subject was shown whether he was right or wrong and then moved on to the next item.

An analysis of the number of errors committed on both immediate recall tests and delayed recall tests showed the general superiority

of the prompting mode of instruction followed by the single-try confirmation mode and finally the single feedback mode of instruction.

Cook and his associates, (Cook and Kendler, 1956), (Cook, 1958), (Cook and Spitzer, 1960), (Cook, 1963) have repeatedly shown the superiority of the prompting mode of instruction over the confirmation mode of instruction.

Stolurow (1963) compared the effects of prompting and confirmation methods of instruction when used to teach a sight vocabulary to educable mentally retarded children. The effects of overlearning were also examined. Subjects were required to choose from among two response alternatives, the response which was displayed with the stimulus. The prompting sequence of events consisted of the subject being shown the stimulus followed by the stimulus paired with the correct response. The subject was then required to select the correct response from among two alternatives. The confirmation sequence of events consisted of the subject being shown the stimulus and then having to choose the correct response from among two alternatives. Following the subject's choice, the correct response was shown. A criterion of 12 or 24 errorless trials was established.

Using the number of trials to criterion, the data supported the hypothesis that prompting produced faster learning than confirmation. The prompting method also resulted in fewer errors to criterion than did the confirmation method. Analysis of retention test data, administered 1, 7, and 28 days after acquisition indicated:

> . . . The relative level of retention resulting from these two sequences differs depending upon the amount of overlearning involved. The prompting S-R sequence results in both better recall and better recognition, for as long as one month, when the amount of over-learning is

> negligible, whereas, the confirmation S-R sequence results in both better recall and recognition, for as long as one month, when the amount of overlearning is appreciable. . . . (Stolurow, 1963, p. 141)

Cain (1967) modified both the stimuli and the degree of overlearning required of his subjects as presented by Stolurow (1963). Cain (1967), using pre-school children, required only five or 12 consecutive correct responses to reach criterion. His results confirmed those of Stolurow (1963). In the early stages of overtraining, the prompting mode of instruction was superior to the confirmation mode of instruction. In the later stages of overtraining, the confirmation mode was more effective.

Briggs (1961) in a second study combined the prompting and confirmation methods of instruction in an effort to increase the number of items retained after a two-week period. Three groups of subjects were employed, each group first receiving the prompting method of instruction. Following an initial ten-minute period, group one received 10 minutes on the single-try method of instruction, a method in which the subject was shown the correct response and moved on to the next item; group two received 10 minutes on the multiple-try confirmation mode where the subject was informed of whether or not his response was correct and then required to try again if his response was incorrect. The third group received five minutes on prompting followed by five minutes of single-try confirmation followed by 10 minutes of multiple-try confirmation. No significant differences were found among the groups.

In summary, it appeared that immediate knowledge of results (confirmation) produced better learning than either delayed knowledge of results or no feedback at all. In addition, the prompting method of

instruction appeared to aid the acquisition of information in a paired-associate setting, and for minimal levels of overtraining, resulted in better retention than did the confirmation method of instruction. Briggs (1961) and Stolurow (1963) indicated that a combination of the two methods of instruction would lead to increased levels of retention, but they failed to obtain data in support of their hypothesis.

Statement of the Model

Based on the learning theories of Guthrie, Voeks, Sheffield, and Skinner and on the research literature related to retroactive and proactive inhibition, it appeared that incorrect responses contribute little of value to the learning process. Incorrect responses become associated with the stimuli present when the responses occur. Provisions must then be made for additional responses to be given in association with the stimuli, decreasing the efficiency of the learning process.

The research literature related to the response latencies of correct and incorrect responses suggested that the latencies of incorrect responses were higher than the latencies of correct responses when both measures are obtained and compared for one individual. Assuming data were available defining the average latency of a correct response for an individual, provisions were made to continually monitor an individual's response latency and compare the current latency to the individual's correct-response latency. Should an individual's latency exceed the correct-response latency, one would predict the occurrence of an incorrect response in advance of the occurrence of that response and modify the sequence of instruction. The sequence of instruction

following the prediction of an error would prevent the subject from overtly making the response and at the same time prompt the subject by showing him the correct response. This method of instruction was tested in the present study.

CHAPTER III

PRE-EXPERIMENT: THE DEVELOPMENT OF MATERIALS

The model developed in Chapter II for the teaching of beginning shorthand through the use of computer-assisted instruction was based on the assumption that data were available for describing an individual's correct-response latency. The purpose of this chapter is to describe the development of the materials used to determine an individual's correct-response latency.

The computer recognizes student responses only when directed to do so by a program. Once an indication is made by the computer that a response is required from the student, by the simultaneous appearance of a small rectangle and the letter K (for keyboard) in the lower right corner of the cathode ray tube, the student must type his response. Upon the completion of his response the student is required to press a special combination of keys on the keyboard to indicate the completion of his response. The process is called "entering," and it serves to signal the computer that one has finished responding. At the completion of each response, the student "enters" his response into the computer. Until a response is "entered" it is held in a buffer and the complete answer is transmitted to the computer at one time.

For the purposes of this study and because of the limitations of the equipment, the term "response latency" was defined as the period of elapsed time between the indication given by the computer that a typed response is required and the signal by the student that he has completed or "entered" his response. Response latency, as defined in

this study included the time necessary for any cognitive activity required to formulate a response, in addition to the time required to type and "enter" the response.

Examination of the 30 beginning shorthand symbols shown in Figure 1, revealed that not all of the response terms consisted of a one-character response. As many as five characters were required as responses. On the basis of the number of characters needed to construct a response, independent of any cognitive activity necessary to formulate the correct response, it was hypothesized that for any given individual, the correct-response latency for one shorthand symbol requiring a one-character response would not equal the correct-response latency for a shorthand symbol requiring a five-character response. It was the purpose of the experiment described in this chapter to collect data to create 15 pairs of shorthand symbols matched on the basis of their correct-response latencies. The two shorthand symbols comprising a matched pair have approximately equal correct-response latencies. Once the matched pairs were established, it was possible to use one item from each pair to collect data for defining an individual's correct-response latency to the second member of the pair.

The model for the teaching of beginning shorthand described in Chapter II utilizes both the prompting and confirmation methods of instruction. Each completed response is confirmed by the display of the correct response following completion of the student's response. Those responses not allowed to reach completion because of action taken by the computer program in response to a predicted incorrect response, are followed by the occurrence of a prompt which displays the correct response to the student. Because of the utilization of the

Stimulus	Response	Stimulus	Response
	S		R
	A		L
	F		H
	V		I
	E		S
	N		P
	M		B
	T		SH
	D		CH
	. (period)		J
	?		OO
	( )		K
	--		G
	-		UN-TH
	0		OV-TH

Fig. 1. List of shorthand symbols used as stimuli.

prompting and confirmation methods of instruction in the model, the prompting and confirmation modes of instruction were treated as independent variables in the current study.

Design of Pre-experiment

Two training methods, prompting and confirmation, were contrasted and three levels of overlearning, 2, 5, and 8 successive errorless trials, were investigated. A retention test was administered seven days following acquisition.

Subjects

Twenty-three students volunteered to participate in the pre-experiment. The students were told that they would be taught the names of 30 elementary shorthand symbols by means of computer-assisted instruction and that they were required to return to the Computer Assisted Instruction Laboratory seven days after the first day of instruction. Each subject was paid two dollars for his participation if he fulfilled both of the above requirements.

Materials

The 30 shorthand symbols shown in Figure 1 were programmed to appear on the cathode ray tube associated with the instruction station of the system. Student responses were accepted by means of a typewriter-like keyboard which is part of the student station.

A utility computer program was written (IBM, 1968) to assign the subjects to one of the pre-experiment treatments. The computer program also controlled the presentation of the stimuli, requested and analyzed student responses, monitored each subject's progress throughout

the pre-experiment, and terminated each subject when he satisfied the criterion dictated by his particular treatment. Once the utility program had begun, the program controlled all aspects of the experiment.

Pre-experiment Procedure

Upon his arrival at the Computer Assisted Instruction Laboratory, the subject was seated in front of an instruction station and the author initiated execution of the utility program for the subject. The utility program instructed the subject concerning how to operate the student station and also instructed the subject how to correct a response he typed before he "entered" his response.

Following instruction related to the operation of the student station, the utility program presented arithmetical problems to the subject for 10 minutes. The purpose of this exercise was to give the subject sufficient practice in typing and "entering" responses at the student station. The author was available throughout this period to assist with problems encountered by the subjects and to answer questions. No data were collected during the practice session.

Ten minutes after the completion of the instructional material related to operation of the student station, the subject was assigned at random to either the prompting or confirmation method and a criterion of 2, 5, or 8 successive errorless trials by the computer. Subjects were instructed to type and enter a response to each stimulus as it was presented. The subjects were advised to guess if they were not sure of the correct response.

The first trial of the pre-experiment was common to all subjects. Each subject was shown in a random order the 30 stimuli, one

at a time, and requested to type and enter the correct name of the symbol. Feedback was not given during this trial. The first trial was designed to measure a subject's previous knowledge of the beginning shorthand alphabet. The first trial is also an example of a testing trial used throughout the remainder of the pre-experiment. Following the first trial, the subject received a training trial utilizing the method of instruction to which he was assigned.

The subjects assigned to the prompting method were trained on those items incorrectly identified according to the following schedule of events. The stimulus, response, and instructions to, "Type the name of the symbol and enter" were displayed simultaneously on the cathode ray tube. The stimuli were presented in the same sequence used during the previous trial. Unknown to the subject, he was allotted 10 seconds to type and enter his response. The stimulus and response remained on the cathode ray tube for 10 seconds before the presentation of the next stimulus-response combination. This procedure was followed until all of the stimuli incorrectly identified during the previous trial were shown to the subject in association with the correct responses. At the completion of a training trial the subject was informed by the utility program that the next series of items would be presented as a test, but, if he wished, he could take a break before beginning the next series of items. Following the optional break, the stimuli on which the subject had not reached criterion were randomly ordered and presented to the subject in the testing mode. Following the testing trial, stimuli incorrectly identified on the previous trial were presented in a

training trial. The testing (no-feedback), training, testing, training . . . sequence was followed until the subject reached criterion on each of the stimuli.

The subjects assigned to the confirmation method were trained on items incorrectly identified according to the following schedule of events. The stimulus and the instructions to, "Type the name of the symbol and enter" were displayed on the cathode ray tube. Following the subject's response, the correct response appeared on the cathode ray tube and remained with the stimulus and the subject's response for 10 seconds. The next stimulus missed during the previous trial was then presented. At the completion of the training trial, just described, the subject was informed by the utility program that the next series of items would be presented as a test, and that he could take a break at this time if he so desired. Following the optional break, a testing trial was administered in which the stimuli on which the subject had not reached criterion were presented in a random order. No feedback was presented during this trial. Following the testing trial, stimuli incorrectly identified on the previous trial were presented in the training mode. The testing, training, testing, training sequence was followed until the subject reached criterion on each of the stimuli.

The retention test administered seven days later was also administered at a student station. Each subject was shown each stimulus once and requested to, "Type the correct name of the symbol and enter." Feedback was not given during the retention test.

Results

No provisions were programmed into the computer to maintain equal cell frequencies. The resulting cell frequencies are shown in Table 1. Although the frequencies were approximately equal for the main effects, individual cell frequencies were not equal. A program error made it impossible to examine the effects of various levels of over-training on retention and the main effects of prompting and confirmation on acquisition and retention. The unequal cell frequencies did not invalidate the main purpose of this pre-experiment, the creation of 15 pairs of stimuli matched on average correct-response latencies.

Table 1

Cell Frequencies Obtained by Random Assignment as Generated by the Computer Program (N=23)

Method of Instruction	Criterion		
	Two	Five	Eight
Prompting	N=7	N=1	N=4
Confirmation	N=1	N=6	N=4

An individual's correct-response latency for a given item may be examined at two points along his response latency profile. A mean correct-response latency can be calculated on the basis of a subject's correct responses prior to the trial on which the last error occurred, or on the basis of a subject's correct responses during the trials following the trial of last error. Examination of the data describing correct-response latencies prior to the trial of last error showed that the data accumulated during those trials were very unreliable. Data summed

across subjects and trials prior to the trial of last error for subjects assigned to the prompting method indicated that as few as zero and as many as 21 correct responses were made to individual items. The average latency ranged from 3.1 seconds to 10.3 seconds and the standard deviations ranged from 10.0 seconds to 50.4 seconds. Similar data were obtained from subjects assigned to the confirmation method. The high variability of these data made it impractical and impossible to create matched pairs of items based on correct-response latencies prior to the trial of last error. Examination of the data shown in Figure 2 illustrates the high variability of the response latencies prior to the trial of last error.

Examination of the data shown in Figure 2 also illustrates the high variability of the response latency data during the trials immediately following the trial of last error. Data summed across subjects and trials on the third trial following the trial of last error for those subjects assigned to the confirmation method indicated that the mean correct-response latencies varied from 3.7 seconds to 4.6 seconds and the standard deviations varied from 0.5 seconds to 5.4 seconds. Similar data were obtained from those subjects assigned to the prompting method.

Because of the high variability of the response latencies on the trials immediately following the trial of last error, it was decided to analyze only the data obtained from the subjects assigned to a criterion of eight consecutive errorless trials. Eight subjects, four from each method of instruction, supplied the data for this analysis.

A median correct-response latency was calculated for each subject on each item. The median was chosen to eliminate the effects

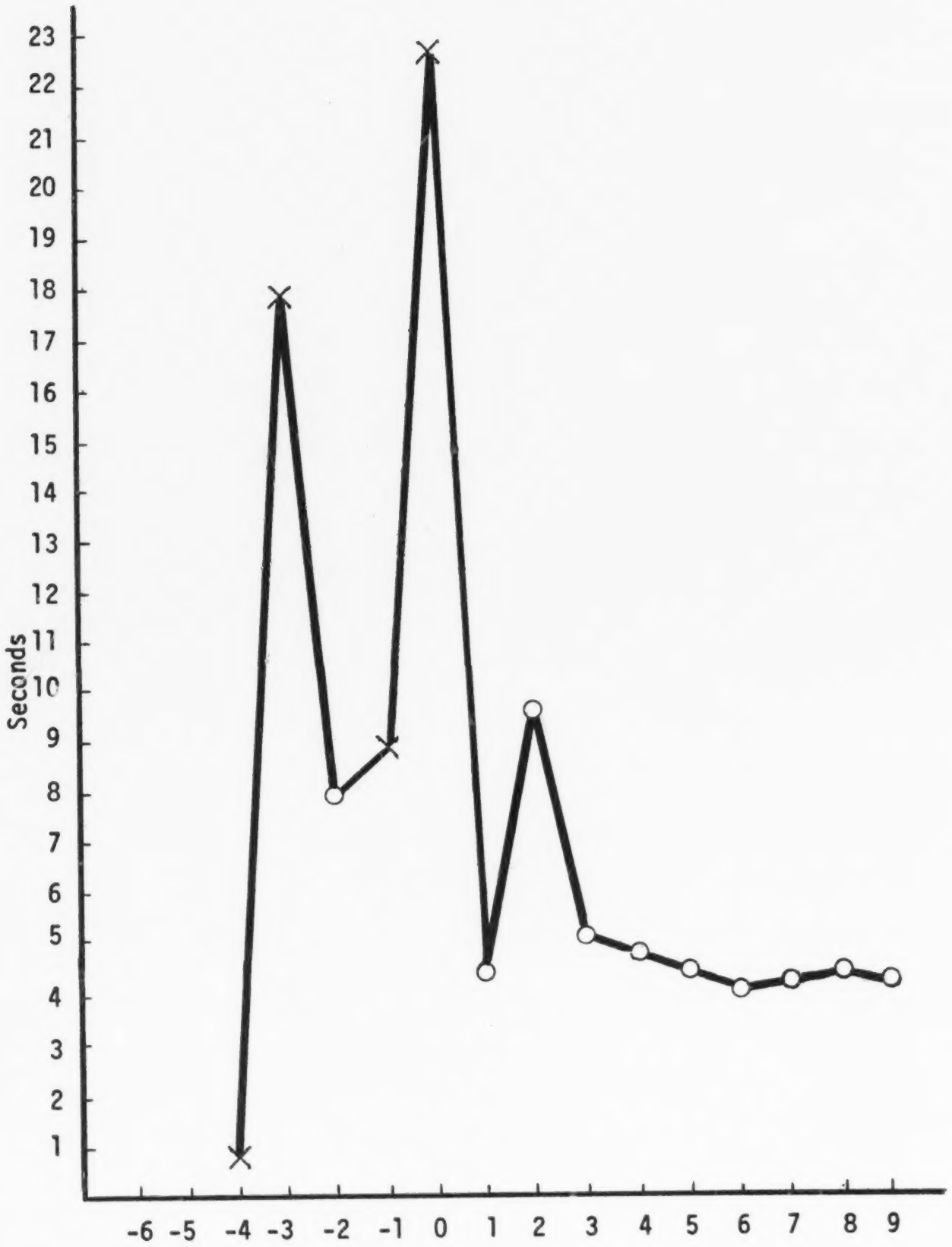


Fig. 2. Response latency profile for one subject on one item.

caused by the high variability of the latencies following the trial of last error. A mean median correct-response latency across all subjects was calculated for each item. The results are shown in Table 2. Analysis of the data using the t-statistic failed to reject the hypothesis that the mean median correct-response latencies were affected by the method of instruction used to collect the data for 29 of the 30 stimuli. The data for the final analysis were collapsed over the method of instruction dimension. Table 3 contains the ranking of the stimuli based on the mean median correct-response latency following the trial of last error.

Fifteen pairs of items were created from the data shown in Table 3. The first two items (items 28 and 27) formed the first pair, the next two items (items 11 and 10) formed the second pair etc., until the last pair was formed by items 22 and 24. Two groups, each consisting of 15 items were then created using a table of random numbers to assign one member of each pair to each group. The results of this procedure are shown in Table 4. One member of each pair was used for the collection of data to predict an incorrect response for the remaining member of the pair.

Post Hoc Verification of Item Pairing

Data collected during the pre-experiment were used in a post hoc test of the accuracy of the item-pairing procedure. Upon the calculation of a median correct-response latency from the data collected from an individual for one item of each pair, the median correct-response

Table 2

Mean Median Correct-Response Latencies and Standard Deviations of the Beginning Shorthand Symbols

Item	Letter-Sound Equivalent	Prompting $\bar{X}$ (Seconds)	Prompting S.D.	Confirmation $\bar{X}$ (Seconds)	Confirmation S.D.	t	p
1	S	2.22	0.64	2.12	0.20	< 1	N.S.
2	. (period)	2.44	0.47	2.62	0.73	< 1	N.S.
3	?	2.93	0.84	2.98	0.75	< 1	N.S.
4	( )	3.33	0.17	3.62	0.69	< 1	N.S.
5	--	2.36	0.59	2.51	1.08	< 1	N.S.
6	-	1.77	0.17	2.25	0.55	1.65	N.S.
7	OO	1.79	0.07	2.75	0.88	2.18	N.S.
8	R	2.87	0.95	3.23	0.42	< 1	N.S.
9	J	2.07	0.14	2.36	0.56	1.00	N.S.
10	H	1.98	0.44	2.13	0.53	< 1	N.S.
11	I	1.96	0.62	1.97	0.39	< 1	N.S.
12	A	2.16	0.51	2.19	0.26	< 1	N.S.
13	S	2.81	1.12	2.28	0.38	< 1	N.S.
14	P	3.18	0.74	3.03	1.02	< 1	N.S.
15	B	2.88	0.66	3.07	0.75	< 1	N.S.
16	SH	3.32	1.16	2.83	0.55	< 1	N.S.
17	CH	3.41	1.14	2.74	0.40	1.12	N.S.
18	L	2.48	0.59	1.93	0.25	1.72	N.S.
19	O	2.33	0.58	2.27	0.29	< 1	N.S.
20	K	2.36	0.35	2.73	0.97	< 1	N.S.
21	G	2.14	0.17	3.11	1.07	1.80	n.s.
22	UN-TH	4.64	0.44	5.68	0.60	2.81	.05
23	F	3.29	1.41	2.76	0.58	< 1	N.S.
24	OV-TH	4.93	0.60	5.96	2.29	< 1	N.S.
25	V	3.26	1.11	2.12	0.40	1.93	N.S.
26	E	2.25	0.55	2.06	0.31	< 1	N.S.
27	N	1.67	0.32	1.81	0.18	< 1	N.S.
28	M	1.48	0.17	1.72	0.33	1.33	N.S.
29	T	2.08	0.33	2.57	0.82	1.11	N.S.
30	D	2.26	0.52	3.17	1.51	1.14	N.S.

Table 3

Ranks of the Beginning Shorthand Symbols by Mean Median Correct-Response Latencies (N=8)

Rank	$\overline{X}$ (Seconds)	S.D.	Item	Letter-Sound Equivalent
1	1.60	0.27	28	M
2	1.74	0.25	27	N
3	1.96	0.48	11	I
4	2.01	0.45	6	-
5	2.06	0.45	10	H
6	2.15	0.43	26	E
7	2.17	0.44	1	S
8	2.18	0.37	12	A
9	2.21	0.51	18	L
10	2.21	0.41	9	J
11	2.27	0.76	7	OO
12	2.30	0.42	19	O
13	2.33	0.64	29	T
14	2.43	0.81	5	--
15	2.53	0.57	2	. (period)
16	2.54	0.82	13	S
17	2.54	0.70	20	K
18	2.63	0.88	21	G
19	2.69	0.98	25	V
20	2.71	1.15	30	D
21	2.96	0.74	3	?
22	2.98	0.66	15	B
23	3.03	1.04	23	F
24	3.05	0.71	8	R
25	3.08	0.88	16	SH
26	3.08	0.86	17	CH
27	3.11	0.83	14	P
28	3.48	0.49	4	( )
29	5.16	0.74	22	UN-TH
30	5.44	1.64	24	OV-TH

Table 4

Correspondence of Items
In Stimulus Sets
A and B

Set A					Set B			
Item	Letter-Sound Equivalent	$\bar{X}$ (Seconds)	S.D.	Corresponds To	Item	Letter-Sound Equivalent	$\bar{X}$ (Seconds)	S.D.
28	M	1.60	0.27		27	N	1.74	0.25
11	I	1.96	0.48		6	-	2.01	0.45
26	E	2.15	0.43		10	H	2.06	0.45
1	S	2.17	0.44		12	A	2.18	0.37
9	J	2.21	0.41		18	L	2.21	0.51
7	OO	2.27	0.76		19	O	2.30	0.42
5	--	2.43	0.81		29	T	2.33	0.64
13	S	2.54	0.82		2	. (period)	2.53	0.57
21	G	2.63	0.88		20	K	2.54	0.70
30	D	2.71	1.15		25	V	2.69	0.98
3	?	2.96	0.73		15	B	2.98	0.66
23	F	3.03	1.04		8	R	3.05	0.71
17	CH	3.08	0.86		16	SH	3.08	0.88
4	( )	3.48	0.49		14	P	3.11	0.83
24	OV-TH	5.44	1.64		22	UN-TH	5.16	0.74

latency was superimposed on the profile of responses already collected for the remaining member of the pair to determine the number of responses that would have been predicted as incorrect responses.

Figures 3 and 4 show an individual's response latency profile for items 27 and 28, a pair of items having relatively low mean median correct-response latencies. The median correct-response latency on item 27 was 1.6 seconds and the median correct-response latency on item 28 was 1.5 seconds. A value of one second was added to each median correct-response latency so as not to incorrectly predict incorrect responses 50 per cent of the time as would occur if only the median value were used. A value of one second was chosen based on the distribution of standard deviations of the mean median correct-response latencies. A horizontal line indicating the maximum response latency permitted to occur without the alteration of the instruction based on a predicted incorrect response has been added to each figure. The line in Figure 3, indicating the maximum allowable response latency for that item was calculated from the data shown in Figure 4. Similarly, the line shown in Figure 4 was calculated from the data shown in Figure 3.

Examination of Figure 3 indicated that the single incorrect response that did occur would not have occurred had the model proposed in Chapter II of this study been used. One correct response, the first response following the trial of last error, would also have been predicted to have been an incorrect response. The remaining seven responses would have occurred, a true prediction since they were correct responses. In summary, only one incorrect prediction would have been made if the model had been in use during the collection of the data in Figure 3.

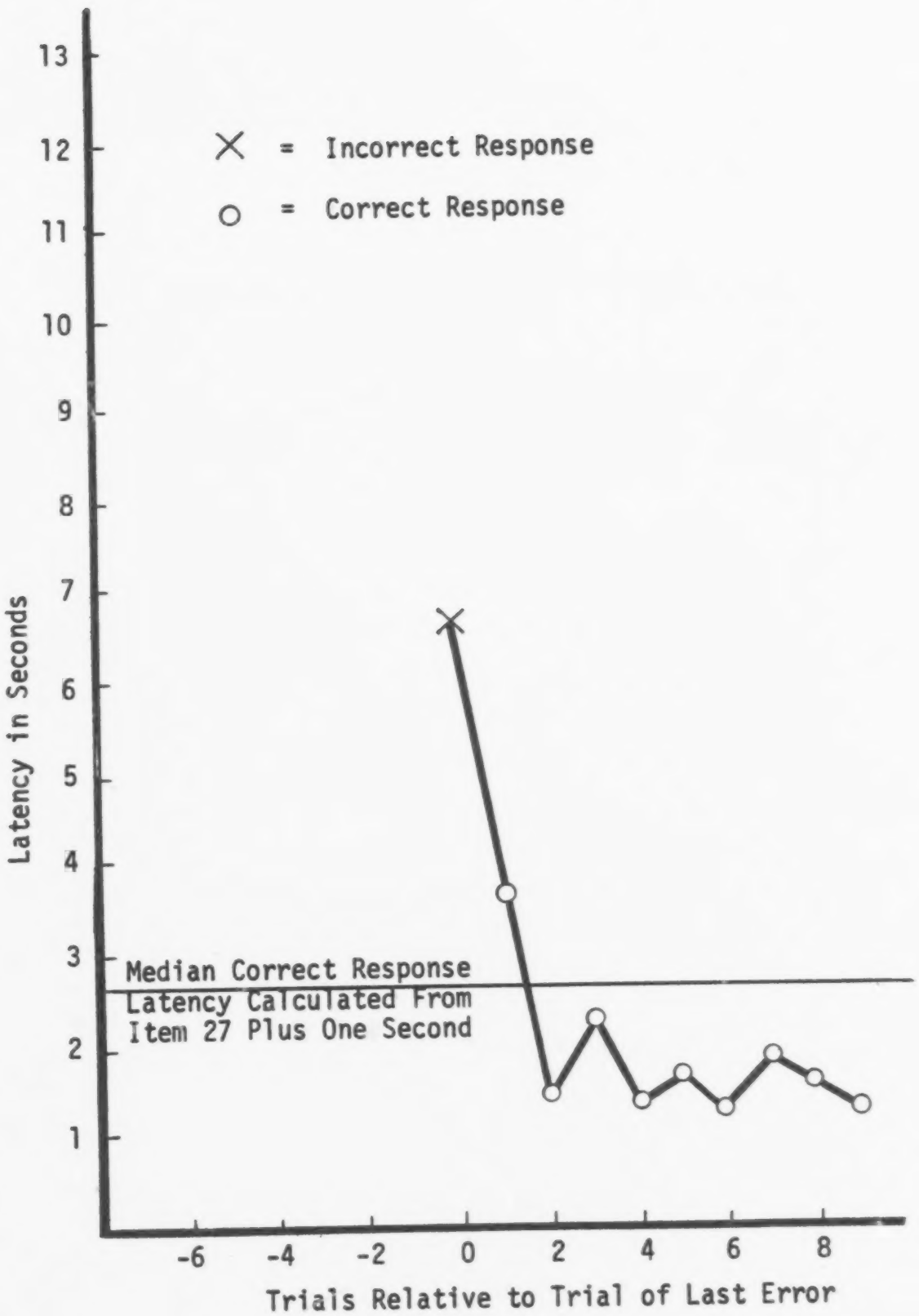


Fig. 3. Subject A's response latency profile for Item 28.

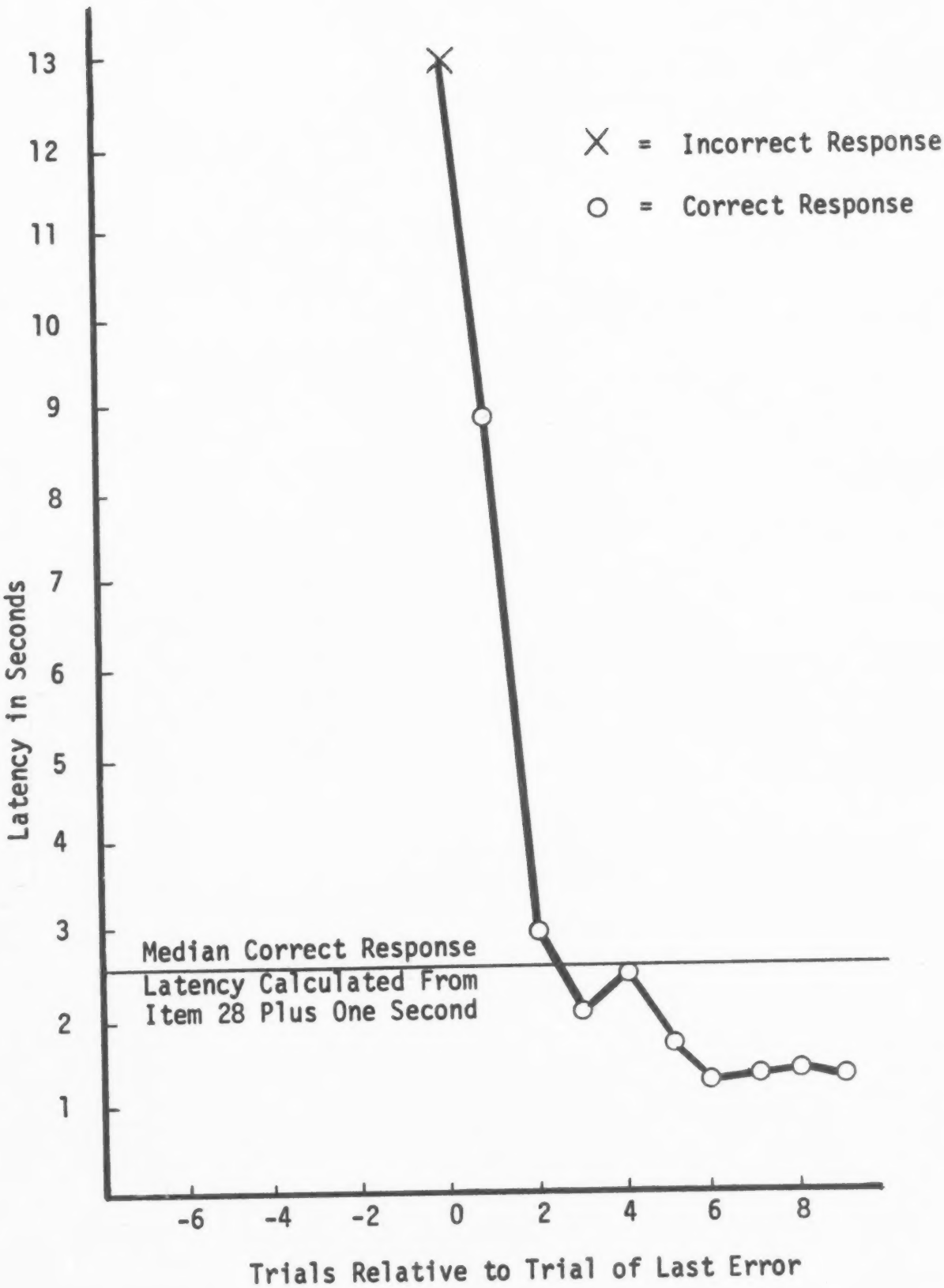


Fig. 4. Subject A's response latency profile for Item 27.

Figure 4 shows the results which may have occurred if data from item 28 had been used to predict incorrect responses for item 27. Only two responses, the first two responses following the trial of last error, would incorrectly have been prevented from occurring.

Figures 5 and 6 show similar information obtained from a different subject on items 22 and 24. These items were found to have the highest mean median correct-response latencies. Had the model been in effect during the collection of the data shown in Figure 5, one of the four incorrect responses would have occurred. The occurrence of the three incorrect responses above the line indicating the maximum allowable correct-response latency would have been prevented and the subject would have been shown the correct answer and moved on to the next stimulus. Three of the eight correct responses would also have been predicted as incorrect and now allowed to occur--an error of prediction.

The data shown in Figure 6 indicate that each of the incorrect responses would not have occurred had the model been used during the instruction session. Only three of the correct responses would have been prevented from occurring.

In summary, it appeared that the methods used to pair the 30 shorthand symbols, and the methods used to predict incorrect responses were useful and capable of actually predicting most incorrect responses. It was the purpose of the remainder of this study to test the effectiveness of the model to teach beginning shorthand through the use of computer-assisted instruction as developed in Chapter II.

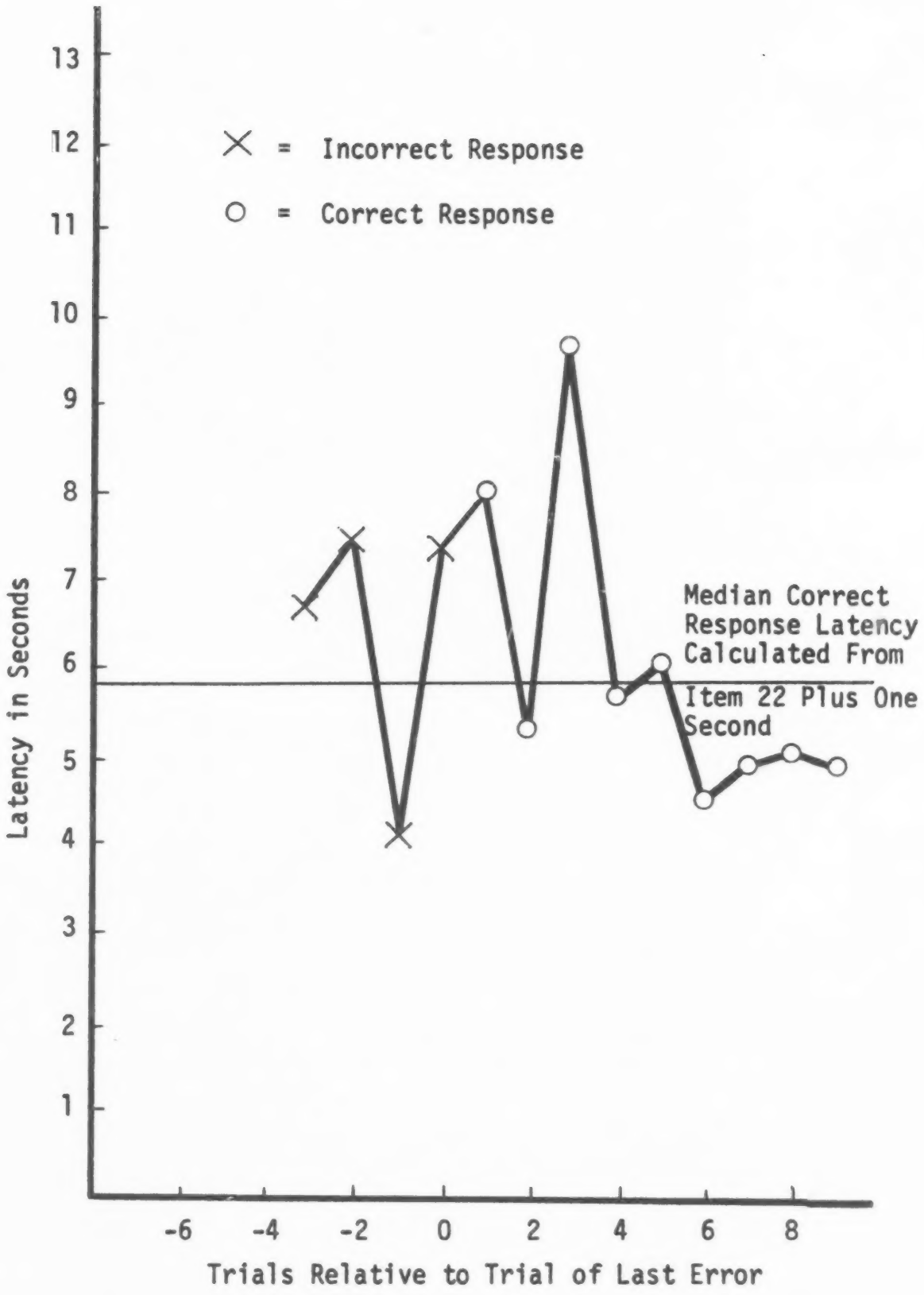


Fig. 5. Subject B's response latency profile for Item 24.

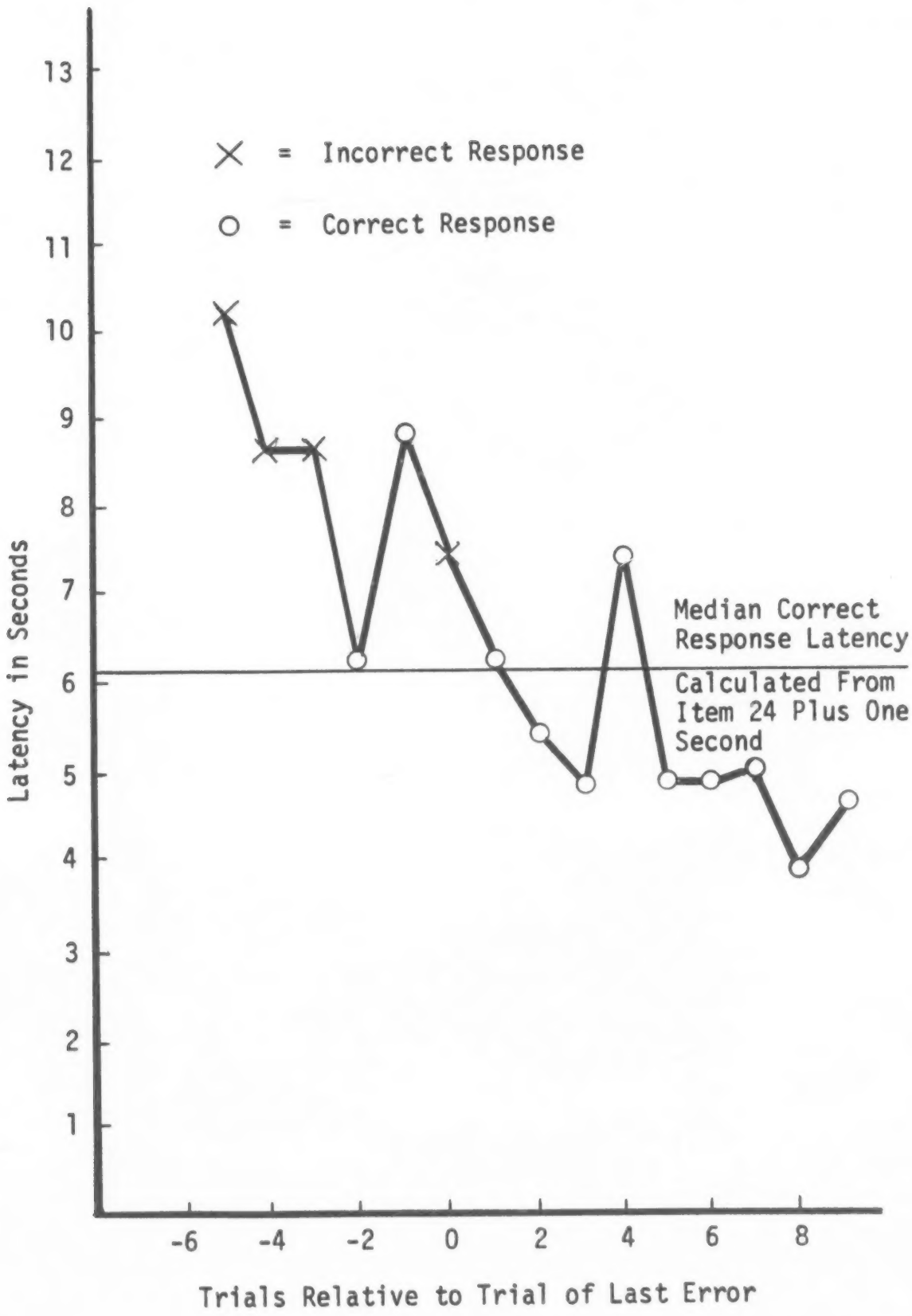


Fig. 6. Subject B's response latency profile for Item 22.

CHAPTER IV

THE EXPERIMENT: TEST OF THE MODEL

The model developed in Chapter II for the teaching of beginning shorthand, here called the "interception" (I) model since predicted incorrect responses are intercepted and prevented from occurring, was contrasted with three other methods of instruction. The prompting (P) and confirmation (C) methods were included in the design because of their close relationship to the interception method of instruction. Each response having a latency less than the established latency for a correct response was confirmed by the presentation of the correct response following the subject's response. In place of a response which might have occurred if an unlimited amount of time were available, a prompt was shown to the subject by the presentation of the correct response. An overt response was not required of the subject. The interception (I) method utilized the theoretical advantages gained by the prediction and prevention of potentially incorrect responses in addition to the advantage gained through the combination of the prompting (P) and confirmation (C) methods; and the advantage of confirmation following each completed response. A fourth method of instruction, a modified confirmation (C') method was used in the study to control the effect of receiving feedback following each response. Subjects learning the shorthand symbols by the modified confirmation method (C') received feedback following each response. Testing trials were not differentiated as they were for those subjects assigned to the confirmation (C) method.

Subjects

Two groups of subjects were recruited from undergraduate classes at The Pennsylvania State University. The first group was offered five dollars each if they agreed to participate in six experimental sessions. Two experimental sessions were required for the acquisition of the task, and four sessions were required for the administration of the retention tests. Subjects in this group consisted primarily of upperclassmen in the College of Education. The second group of subjects was offered a choice between four dollars or 12 points which could be applied to their grade in a class in introductory educational psychology if they agreed to participate in four experimental sessions. Scheduling limitations permitted the administration of only two retention tests to the second group of subjects. Subjects in the second group were primarily underclassmen from various colleges of the University.

A total of 140 subjects volunteered to participate in the experiment. Of the 140 subjects, 20 subjects were excluded from the analysis because of: failure to comply with the requirements of the experiment (N=10); computer failure (N=7); or experimenter error (N=3). Ten subjects were assigned to each experimental cell. Of the 120 subjects who completed the experiment, 54 subjects were administered two retention tests and 66 subjects were administered four retention tests. Fifty-six men and 64 women participated in the experiment, and 13 of the subjects had had earlier instruction in shorthand notation.

Experimental Design

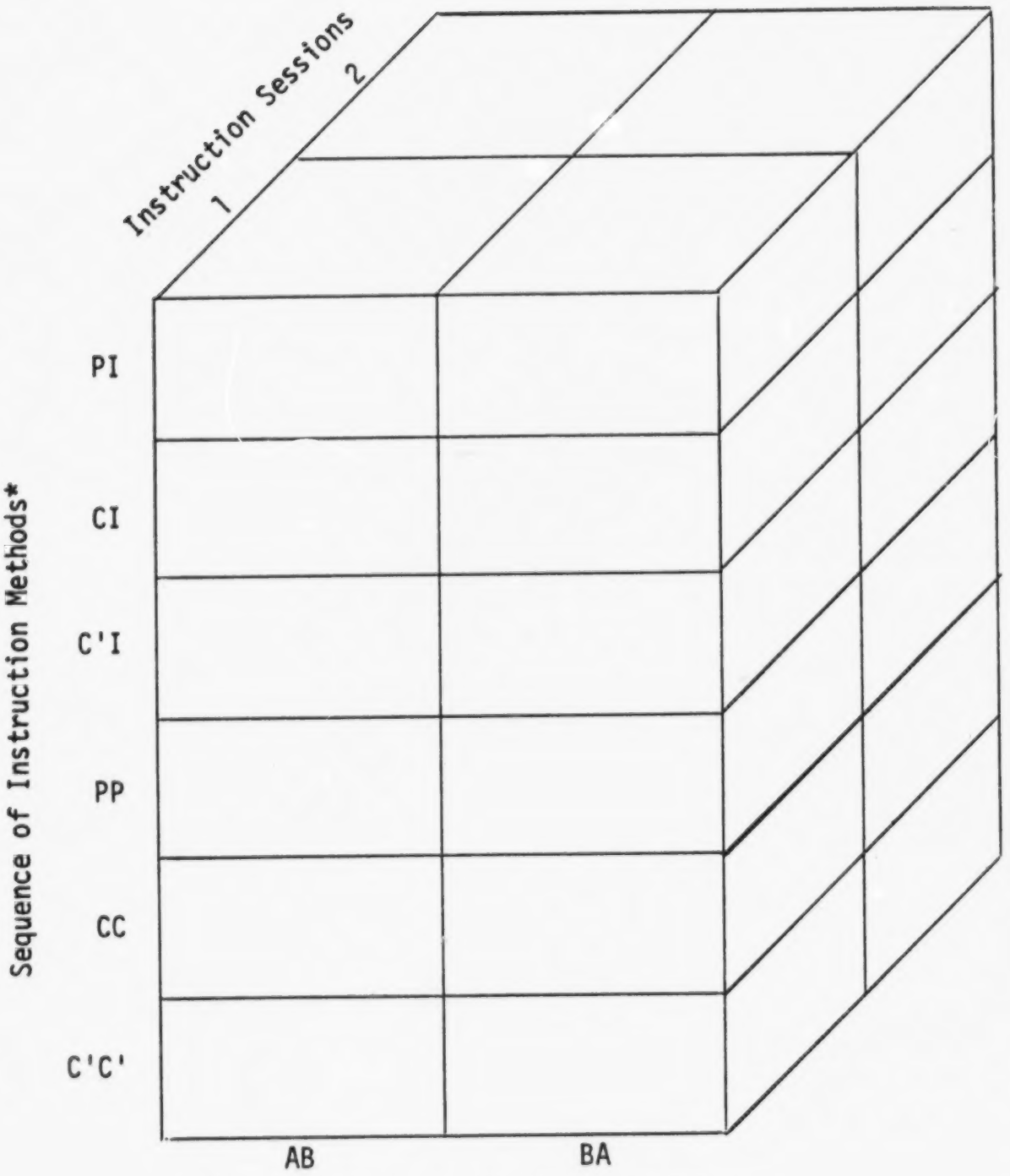
A three-dimensional Lindquist type III (Lindquist, 1953) design was used for the analysis of the data. The design is shown graphically

in Figure 7. Data describing each subject's performance were obtained at the completion of each of the two instruction sessions, accounting for the repeated factor of the design. The remaining two "between" components of the design were the order of stimulus set presentation, either AB or BA, and the sequence of instruction methods administered to the subject during each instruction session.

The instruction methods factor consisted of six entities. The first instruction method of each entity was used during the first instruction session and the second method was used during the second session.

A total of 60 of the 120 subjects were assigned to three control groups. Each subject in a control group received the same instruction method during the second instruction session as he received during the first instruction session. For example, those subjects who were taught the correct stimulus-response associations to the first stimulus set by the prompting method were also taught the correct stimulus-response associations to the second stimulus set by the prompting method.

The remaining 60 subjects received a different method of instruction during each of the two sessions. Each of the 60 subjects was taught the correct stimulus-response associations by the interception method during the second session. The subjects learned the correct stimulus-response associations during the first instruction session by either the prompting, confirmation, or modified confirmation method. Correct-response latency data, used with the interception method during the second instruction session, were collected during the first instruction session.



P = Prompting Method of Instruction

C = Confirmation Method of Instruction

C' = Modified Confirmation Method of Instruction

I = Interception Method of Instruction

*One method of instruction was administered at each instruction session.

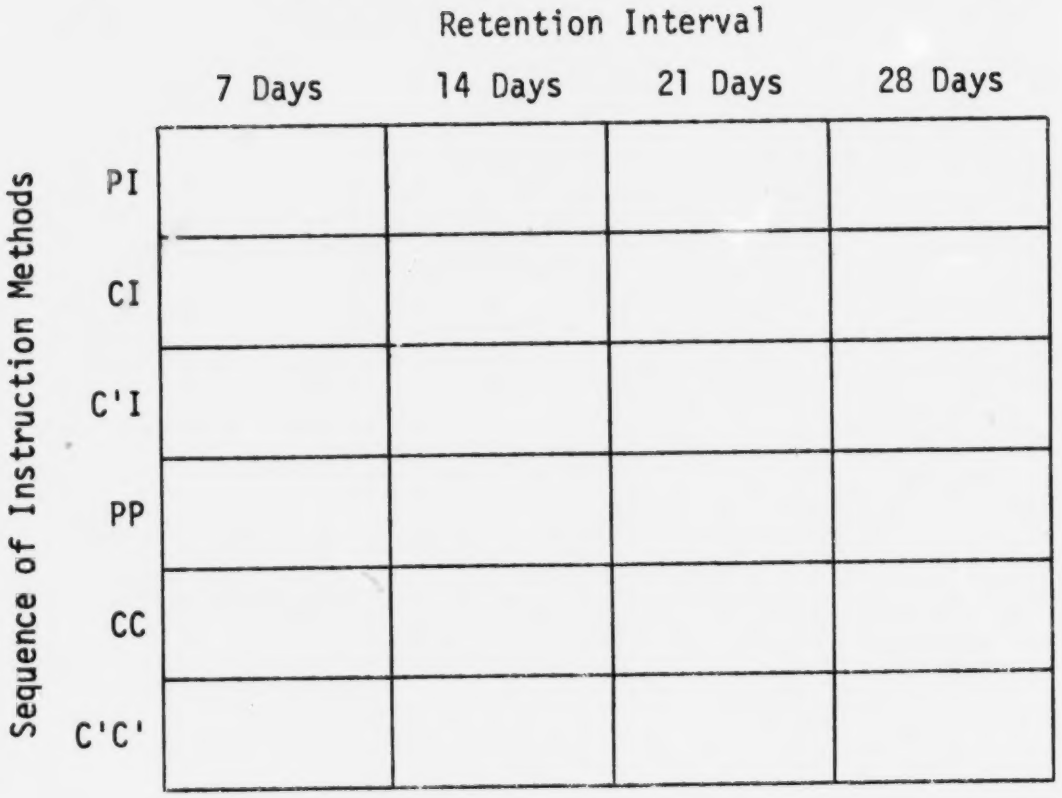
Fig. 7. Experimental design.

Two instruction sessions were required for the acquisition of the stimuli. One set of 15 stimuli was administered at each instruction session. The order of the presentation of the stimulus sets was randomized, one-half of the subjects receiving set A during the first instruction session followed by the administration of set B during the second instruction session. The order of stimulus set presentation was reversed for the remaining subjects. Approximately 24 hours elapsed between instruction sessions.

A different design, a Lindquist Type I (Lindquist, 1953) design, was used for analysis of the retention data (see Figure 8). Two separate analyses were computed because only retention data from the second instruction session were used. Subjects who learned the A set of stimuli during the second session were the source of the data for one analysis and data from the subjects who learned the B set of stimuli during the second session were used in the second analysis. The "between subjects" dimension was the sequence of instruction methods used during the first two sessions.

Materials

Two equated sets of stimuli, each consisting of 15 shorthand symbols were programmed to appear on the cathode ray tube of the student station. The stimuli were created from the shorthand symbols shown in Figure 1. As described in Chapter III, the sets of stimuli were matched, based on each item's mean median correct-response latency. The procedure resulted in the creation of two parallel sets of stimuli. The stimuli assigned to each group are shown in Table 4.



P = Prompting method of instruction

C = Confirmation method of instruction

C' = Modified confirmation method of instruction

I = Interception method of instruction

Note: Separate analyses were computed for subjects learning stimulus A and stimulus set B during the second instruction session.

Fig. 8. Lindquist Type I design used for analysis of retention data.

A computer program was written to control all aspects of the experiment. The computer program taught the subjects the proper use of student station; allowed each subject to practice operating the student station; assigned the subjects to one of 12 experimental groups; presented the stimuli to the subject; requested and analyzed each subject's responses and response latencies; prescribed the instructional treatment to be administered to each subject based on his performance and experimental assignment; monitored each subject's progress throughout the

experiment, and terminated each subject when he met the criterion. Each subject's sequence of events conformed to the criterion established by the subject's experimental assignment.

Procedure

Upon arrival at the Computer Assisted Instruction Laboratory, each subject was given a seat in front of a student station. The introductory program described in Chapter III was used to acquaint the subject with the use of the student station.

Following the ten-minute practice session the computer program assigned each subject to one of the 12 groups. The following instructions were shown to the subject on the cathode ray tube:

> You will now be shown 15 Gregg shorthand symbols. Your job is to learn the correct names of the symbols so you can get each item right nine times in a row. The first time you see the symbol you probably won't know the correct name, so just enter. If you think you know the correct name, type it because this will make your task easier. None of the items will require a response longer than five characters. Be sure to enter after typing each response.

Four methods of instruction were used in various combinations. The prompting (P) method was similar to the prompting method described in Chapter III. During the first trial, a testing trial, the stimuli were presented in a random order to the subject. The subject was required to, "Type the name of the symbol and enter." Feedback was not presented during a testing trial.

A training trial followed each testing trial on which incorrect responses occurred. The stimuli incorrectly identified during a testing trial were randomly ordered and shown to the subject in association with the correct response. Only one stimulus-response pair was shown to the

subject at a time. The subject was instructed to, "Type the name of the symbol and enter." A maximum of 10 seconds was allowed for a response. Each stimulus-response pair remained on the cathode ray tube for 10 seconds before the next incorrectly identified stimulus-response pair was shown to the subject.

After the presentation of the last stimulus-response pair missed during the most recent testing trial, another training trial was presented consisting of a random ordering of all the stimuli on which the subject had not reached criterion. Stimuli missed during that trial were randomly ordered and presented in the following training trial. A training trial was not presented following those testing trials on which incorrect responses did not occur.

The subject was informed of the type of trial to be presented and was given the opportunity to take a break before the start of the next trial.

The testing, training, testing, training . . . sequence continued until each item was correctly identified on nine consecutive trials. As the subject reached criterion on each stimulus, that item was automatically removed from the testing, training sequence.

The confirmation (C) method employed the same pattern of trials as the prompting method. The sequence of events during the training mode was modified for the confirmation method. After the presentation of the stimulus during a training trial, the subject was instructed to, "Type the name of the symbol and enter." Following the subject's response, the correct response appeared on the screen of the cathode ray

tube with the stimulus and the subject's response for 10 seconds. The next incorrectly identified stimulus then appeared on the screen, and a response was requested from the subject.

A modified confirmation (C') method was employed to control for the effect of receiving feedback following each response. Subjects assigned to the prompting and confirmation methods were shown the correct responses only on training trials. Testing and training trials were not differentiated from each other for those subjects who received the modified confirmation method. During each trial, each stimulus for which the subject had not reached criterion appeared on the screen of the cathode ray tube and the subject was requested to, "Type the name of the symbol and enter." Following the subject's response, the correct response appeared on the cathode ray tube together with the stimulus and the subject's response for 10 seconds. The next stimulus then appeared on the cathode ray tube and a request was made for a response. Stimuli were randomly ordered for each trial, and the subject was notified of the beginning of each trial and informed that he could take a break at that point if he so desired.

The interception (I) method, derived from the model developed in Chapter II, was the fourth method of instruction employed in this study. The interception method was based on the assumption that a median correct-response latency has been obtained for each member of the set of materials not being taught by the interception method. The assumption also was required that a direct correspondence exist between the stimuli of the matched sets. Data were presented in Chapter III to support the assumption that the two sets of stimuli used in this experiment were matched. The necessity of having data available defining each

stimulus's median correct-response latency for a subject demanded that the interception method be administered to a subject following the administration of one of the other methods of instruction. The first method of instruction administered to the subject was used to determine each stimulus's median correct-response latency for that subject.

Upon the presentation of a stimulus, randomly selected from the stimuli which had not been correctly identified on nine consecutive trials, the subject was allotted a period of time in which to type a response. The period of time was different for each stimulus because the time allotment was equal to the subject's median correct-response latency obtained from the corresponding item of the stimulus set used during the previous session, plus one second. The duration of the time in which the subject was required to respond was not known to the subject. The sequence of events following the computer program's request for a response was determined by the subject's response latency.

The confirmation method was employed for each response having a latency less than the amount of time allotted for a response. Following completion of the subject's response, the correct response was displayed in association with the stimulus and the subject's response for 10 seconds. Another stimulus, randomly selected from the stimuli which had not been correctly identified on nine consecutive trials was then displayed.

The prompting method was used whenever the subject failed to complete a response within the time period normally required for a correct response to an item with a similar median correct-response latency. After the subject's response latency equaled the amount of time allotted for a response by the computer program, the request for a response from

the subject was erased and the correct response to the stimulus displayed to the subject for 10 seconds. The next stimulus then appeared on the cathode ray tube and the subject was required to, "Type the correct name of the symbol and enter."

Each subject was informed of the beginning of a new trial and was allowed to take a break if he desired.

Subjects in each experimental method of instruction were required to correctly identify each stimulus a tenth time after they had correctly identified each stimulus nine consecutive times. The final test was presented to control forgetting resulting from retroactive inhibition. Experimental conditions were identical to those used during the testing sequence except that feedback was not presented following a response. Stimuli incorrectly identified on this trial were again taught to a criterion of nine consecutive correct identifications by the method of instruction employed during the experimental session. Upon satisfaction of the nine-trial criterion, the 15 stimuli were again presented to the subject. Incorrectly identified stimuli were again recycled through the training sequence. The experimental session was terminated upon the correct identification of all of the stimuli.

The time required to complete each experimental session, excluding time used during a break, the number of correct responses, and the number of incorrect responses were recorded for each subject.

Retention tests were administered at four intervals following completion of the second experimental session. The administration of the retention tests was also performed by the computer program. All of the stimuli were randomly ordered and presented one at a time to the

subject. The subject was instructed to, "Type the name of the symbol and enter." Fifteen minutes were allotted for each response and no feedback was presented. The number of stimuli correctly identified was recorded for each of the two sets of stimuli.

Anticipated Results

Using time-required-to-reach-criterion as the dependent variable, it was expected that the subjects learning the beginning shorthand alphabet assigned to the interception method would require less time to reach criterion than subjects assigned to the prompting, confirmation, or modified confirmation method. It was further expected that subjects assigned to the confirmation method would require the greatest amount of time to reach criterion and that subjects assigned to the modified confirmation method would require less instructional time to reach criterion than subjects assigned to the prompting method. In summary, the ordering of instructional methods based on the amount of time required to reach criterion, from the method requiring the least amount of time was expected to be: interception; modified confirmation; prompting; and confirmation method of instruction.

Analysis of the results obtained using the number of correct responses required to reach criterion as the dependent variable, was expected to reveal no significant differences among the four instruction methods. However, it was also expected that subjects assigned to the interception method would make fewer incorrect responses than subjects assigned to the remaining instruction methods.

It was expected that an analysis of the number of responses correctly recalled at each of the four retention intervals, would result

in the same ordering of instruction methods as resulted from the analysis of time-required-to-reach-criterion. Subjects assigned to the interception method were expected to correctly recall a greater number of responses than subjects assigned to the modified confirmation method. Further, subjects assigned to the prompting method were expected to correctly recall a greater number of responses than subjects assigned to the confirmation method, but a fewer number of responses than subjects assigned to the modified confirmation method.

It was further expected that the factor designated as "order of stimulus set presentation" would have no effect on the outcomes of the experiment. Data describing a subject's correct-response latency obtained from stimulus set A and used to predict incorrect responses to stimuli in set B were expected to be as reliable as data obtained from stimulus set B used to predict incorrect responses to stimuli in set A. Both sets of stimuli were expected to require equal amounts of time and similar numbers of correct and incorrect responses to match the established criterion because of the methods employed in Chapter III to create the two stimulus sets.

CHAPTER V

RESULTS

Three dependent variables were used to test the efficacy of the interception method of instruction. The dependent variables used during the acquisition of the stimulus-response associations were: the amount of time required by each subject to match the established criterion of 10 consecutive errorless trials; the number of correct responses made by each subject before matching the established criterion; and the number of incorrect responses made by each subject before matching the criterion. Two measures of each dependent variable were recorded for each subject, each measurement being made following completion of each of the two instruction sessions.

A significant interaction was expected between the sequence of instruction methods factor and the instruction sessions factor when the dependent variable of time or incorrect responses was used. It was expected that the various instruction methods administered at each instruction session would affect the means associated with each dependent variable.

A non-significant interaction between order of stimulus set presentation and instructional sessions was also expected. A non-significant interaction would provide additional evidence to support the methods described in Chapter III to create two equated sets of stimuli. A significant interaction would indicate that one of the two sets of stimuli was inferior to the other set, thereby adding an additional source of variance to the data.

The second instruction session was of primary interest to this study. The interception method was administered only at this session because of the requirement that correct-response latency data be available in order to implement the interception method. The administration of the interception method, in addition to the prompting, confirmation, and modified confirmation methods, during the second session was the reason for the expected interaction between sequence of instruction methods and instruction sessions. When the interaction between sequence of instruction methods and instruction sessions was significant, an additional analysis was computed using data obtained from the second instruction session

Time-to-Reach-Criterion

The expectation that subjects assigned to the interception (I) method of learning the beginning shorthand alphabet would require less instructional time to reach the criterion of 10 consecutive errorless trials for each stimulus than subjects assigned to the remaining three instruction methods was examined by testing the null hypothesis in an analysis of variance procedure for repeated measures. The dependent variable was the time, measured in minutes, which elapsed from the point the subject was presented the first trial of the experiment to the point the subject satisfied the criterion. Ten subjects were used in each experimental treatment. The Chi-square value of 40.709 (df=11) obtained from Bartlett's test for homogeneity of variance of the treatments was significant beyond the .05 level. The hypothesis of homogeneity of variance was rejected. Kirk (1968) and Winer (1962) agree that the F statistic is robust to violations of the homogeneity of variance

assumptions when equal N's are used. Under these conditions, violations of the homogeneity of variance assumption should not invalidate the between-factors results of interest in this study.

The data support the wisdom of developing a method in Chapter III to create two equivalent sets of stimuli. The interaction between order of stimulus set presentation and instruction sessions was non-significant ($F < 1.0$).

The interaction (see Figure 9) between sequence of instruction methods and instruction sessions was significant at the .001 level ($F=39.4$, $df=5,108$). The significant interaction was anticipated in that each instruction method should require a different amount of time to reach criterion. A test of the homogeneity of the covariance matrices of the independent groups produced a Chi-square of 112.32 ($df=33$), significant beyond the .05 level. The results of this test did not permit the use of a pooled error term for within subject tests. A second analysis of variance was computed to determine the relative effectiveness of the instruction methods used during the second instruction session.

The homogeneity of variance assumption required for the analysis of variance procedure was again violated by the data (Chi-square = 71.10, $df=11$). However, the F distribution is robust to violations of the homogeneity of variance assumption when equal cell frequencies are used. Caution should still be used in interpreting the results of the analysis of variance.

Data obtained from the subjects assigned to the interception method were combined and compared to the data obtained from subjects assigned to the prompting, confirmation, or modified confirmation

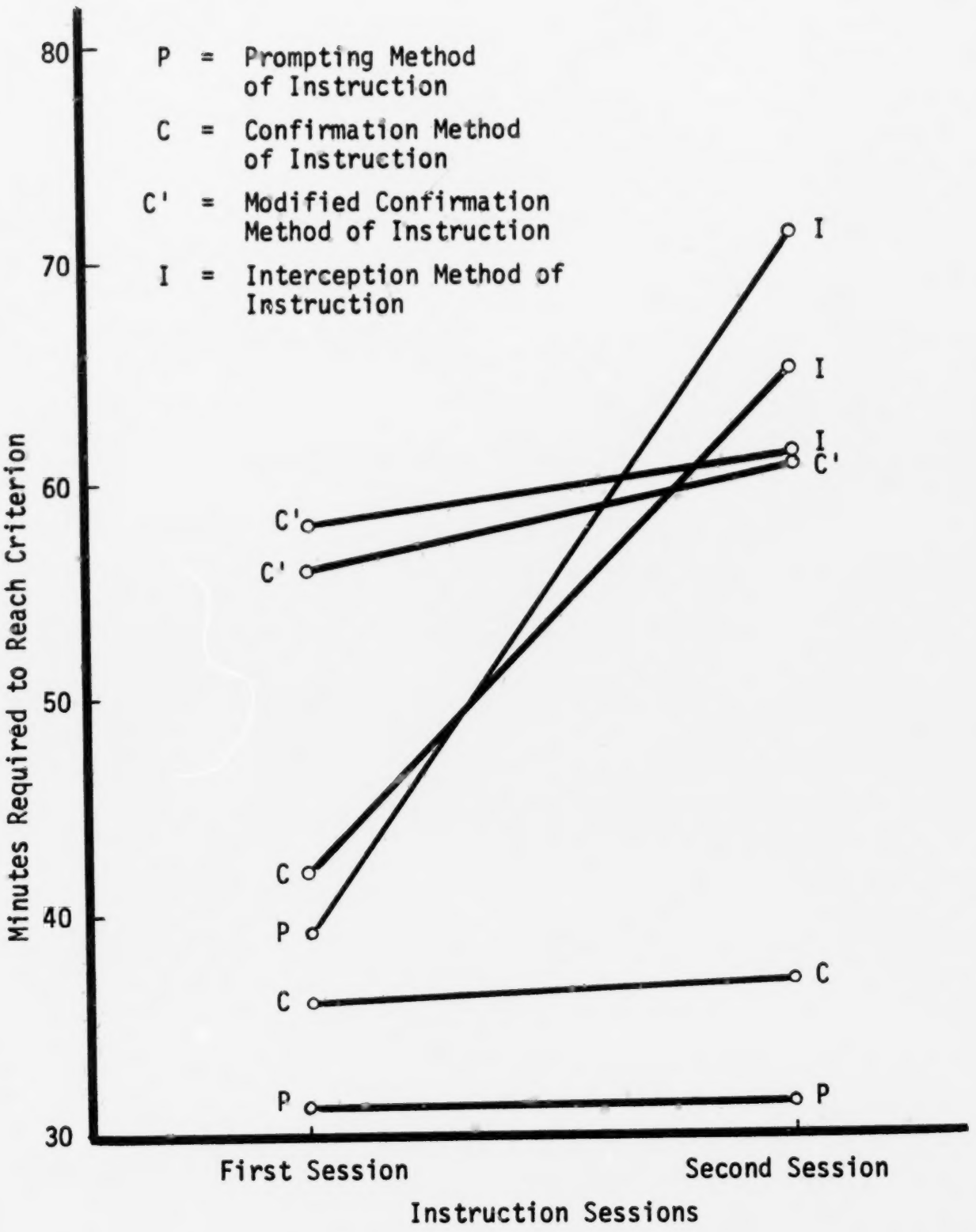


Fig. 9. Interactions between sequence of instruction methods and instruction sessions using time-to-reach-criterion as the dependent variable.

method. Scheffe's S method (Scheffe, 1953), a conservative test for determining the statistical significance of complex contrasts, was used to compare the means obtained from subjects assigned to each of four instruction methods. The results are shown in Table 5. Subjects assigned to the interception method (N=60) required an average of 66.3 minutes to reach criterion during the second instruction session. Subjects assigned to the modified confirmation method (N=20) required an average of 52.55 minutes. The modified confirmation method was similar to the interception method because the correct response was displayed to the subject for 10 seconds each time a stimulus was presented. The correct response was displayed to subjects assigned to the prompting or confirmation method only on trials following testing trials where an incorrect response was made.

Subjects assigned to the prompting method (N=20) required an average of 27.30 minutes to reach criterion. Subjects assigned to the confirmation method (N=20) required an average of 31.65 minutes to match the established criterion.

The results were opposite to the expectation, based on Guthrie's theory, that subjects assigned to the interception method would require less time to reach criterion than subjects assigned to the remaining three methods of instruction. The results also failed to support the notion that subjects assigned to the confirmation method would require the greatest amount of time to reach criterion. The data indicate that the subjects assigned to the modified confirmation method required more time than the subjects assigned to either the prompting or confirmation method. No differences were observed between subjects assigned to the

Table 5

Summary of Multiple Comparisons Computed by Scheffe's S Method for the Second Instruction Session Using Time-to-Reach-Criterion as the Dependent Variable

	Instructional Method						Critical Difference	Probability
	I_P	I_C	$I_{C'}$	P_P	C_C	$C'_{C'}$		
N	20	20	20	20	20	20		
Mean	71.75	65.30	61.05	27.30	31.65	52.55		
Comp.	-1/3	-1/3	-1/3	+1	0	0	13.13	< .05
	-1/3	-1/3	-1/3	0	+1	0	13.16	< .05
	-1/3	-1/3	-1/3	0	0	+1	13.16	< .05
	0	0	0	-1	0	+1	16.11	< .05
	0	0	0	0	-1	+1	16.11	< .05
	0	0	0	-1	+1	0	16.11	N.S.

Note: Subscript indicates method of instruction used during first instruction session.

prompting or confirmation method at the .05 level of significance. Subjects assigned to the prompting and confirmation methods required the least amount of time to correctly identify each stimulus on nine consecutive trials.

Number of Correct Responses

A minimum of 150 correct responses were required to meet criterion assuming that no incorrect responses occurred after the first correct response on each item. Unequal cell frequencies were caused by a modification to the computer program which occurred after the start of the experiment. A total of six subjects' data were excluded from the

analysis using the dependent variable of number of correct responses which occurred before criterion was obtained. The homogeneity of variance assumption was violated as indicated by Bartlett's test of the assumption (Chi-square=101.593, df=11). Since unequal cell frequencies were used in this analysis, caution should be used in interpreting the results. The results of this analysis further support the methods described in Chapter III used to create the two sets of stimuli. The interaction between order of stimulus set presentation and instruction sessions was non-significant ($F < 1.0$). The interaction of sequence of instruction methods and instruction sessions was statistically significant. The interaction is shown in Figure 10.

An analysis of variance procedure developed for unequal cell frequencies was employed to analyze the effects present during the second instruction session, the experimental session at which the four experimental instruction methods were used.

Bartlett's test for homogeneity of variance produced a Chi-square of 209.72 (df=11) significant beyond the .05 level. Interpretation of the results of this analysis must be made with caution.

Subjects who learned the stimulus-response associations during the second instruction session by the interception method (N=57) required an average of 198.9 correct responses to match the established criterion of 10 consecutive correct identifications associated with each stimulus. These subjects made more correct responses than subjects assigned to the prompting (N=20, $\overline{X}$=153.6) or modified confirmation method (N=20, $\overline{X}$=155.6). Subjects assigned to the prompting, confirmation, or modified confirmation method required similar numbers of correct responses to reach the criterion. The results of Scheffe's S

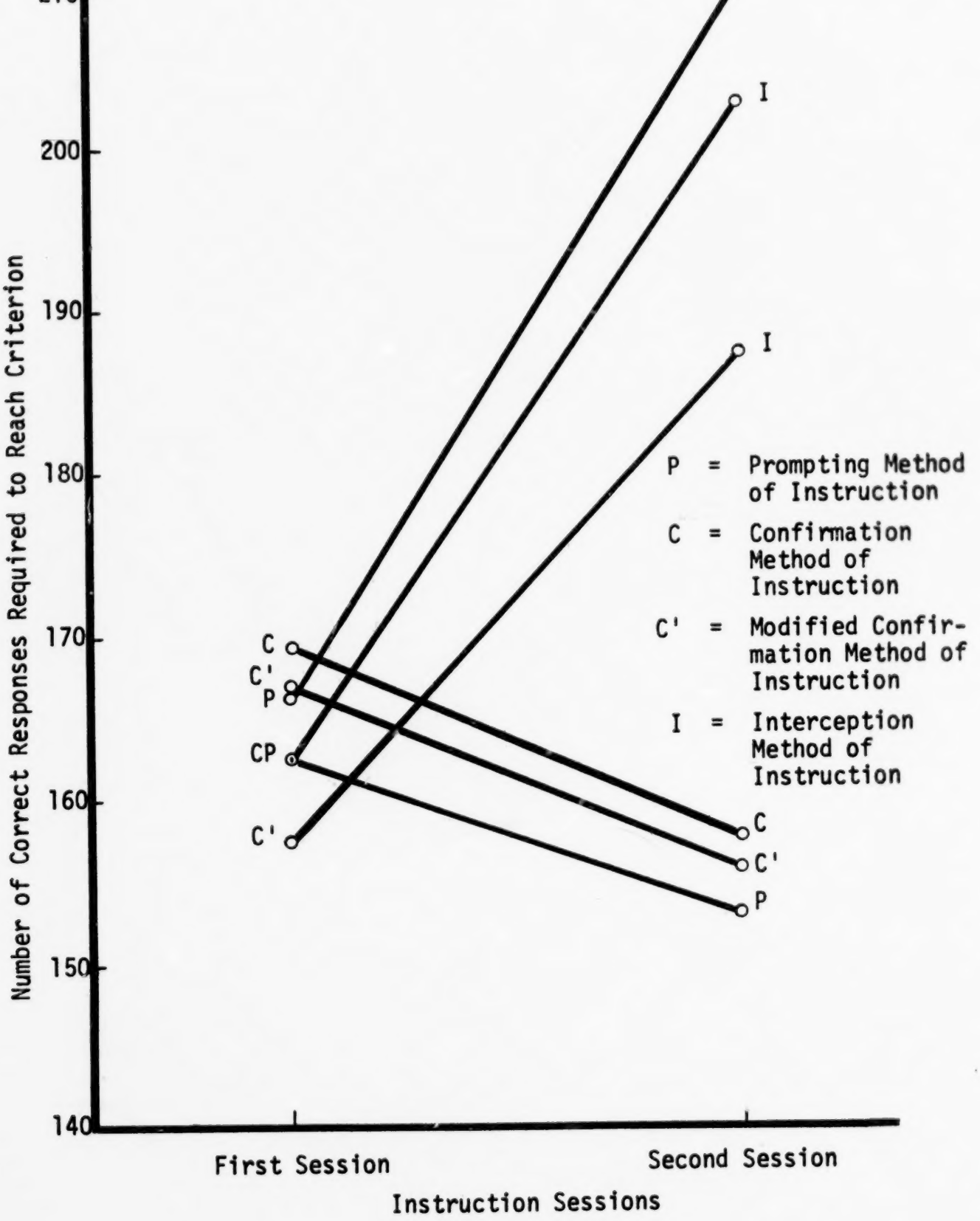


Fig. 10. Interactions between sequence of instruction methods and instruction sessions using the number of correct responses during acquisition as the dependent variable.

method for complex comparisons are shown in Table 6. This result was in opposition to the null hypothesis that all subjects would require equal numbers of correct responses to reach the criterion.

Table 6

Summary of Multiple Comparisons Computed by Scheffe's S Method for the Second Instruction Session Using Number of Correct Responses During Acquisition as the Dependent Variable

	Instructional Method						Critical Difference	Probability
	I_P	I_C	$I_{C'}$	P_P	C_C	$C'_{C'}$		
N	20	20	20	20	20	20		
Mean	210.6	202.8	183.0	153.6	158.4	155.6		
Comp.	-1/3	-1/3	-1/3	+1	0	0	39.42	< .05
	-1/3	-1/3	-1/3	0	+1	0	41.92	N.S.
	-1/3	-1/3	-1/3	0	0	+1	39.42	< .05
	0	0	0	-1	+1	0	50.03	N.S.
	0	0	0	-1	0	+1	47.96	N.S.
	0	0	0	0	-1	+1	50.05	N.S.

Note: Subscript indicates method of instruction used during first instruction session.

Number of Incorrect Responses

The number of overt incorrect responses prior to satisfaction of the criterion was examined by an analysis of variance procedure. Equal cell frequencies were not maintained because of a modification incorporated into the computer program after six subjects had been through the program. It was expected that subjects assigned to the interception

method would make fewer incorrect responses than subjects assigned to either the prompting, confirmation, or modified confirmation method.

Bartlett's test for homogeneity of variance was not violated. The interaction between order of stimulus set presentation and instruction sessions was not statistically significant providing additional evidence in favor of the methods used in Chapter III to create two similar sets of stimuli. The interaction between sequence of instruction methods and instruction sessions reached beyond the .05 level of significance. The finding was in agreement with the expectation that subjects assigned to the interception method of instruction would make fewer errors than subjects assigned to the remaining methods of instruction. The interaction is shown graphically in Figure 11.

An analysis of variance for unequal subclass numbers was computed using the data obtained from the second instruction session. It was during this session that all of the instruction methods were employed since the interception method required data obtained from an earlier experimental session.

The homogeneity of variance assumption was not violated. The method-of-instruction treatment effect reached the .05 level of significance. The results of Scheffe's S method for determining the level of significance for comparisons between various levels of the treatment are shown in Table 7.

Subjects assigned to the prompting, confirmation, and modified confirmation methods made an average of 22.9 incorrect responses before matching the criterion. Subjects assigned to the interception method only made an average of 11.3 incorrect responses before matching

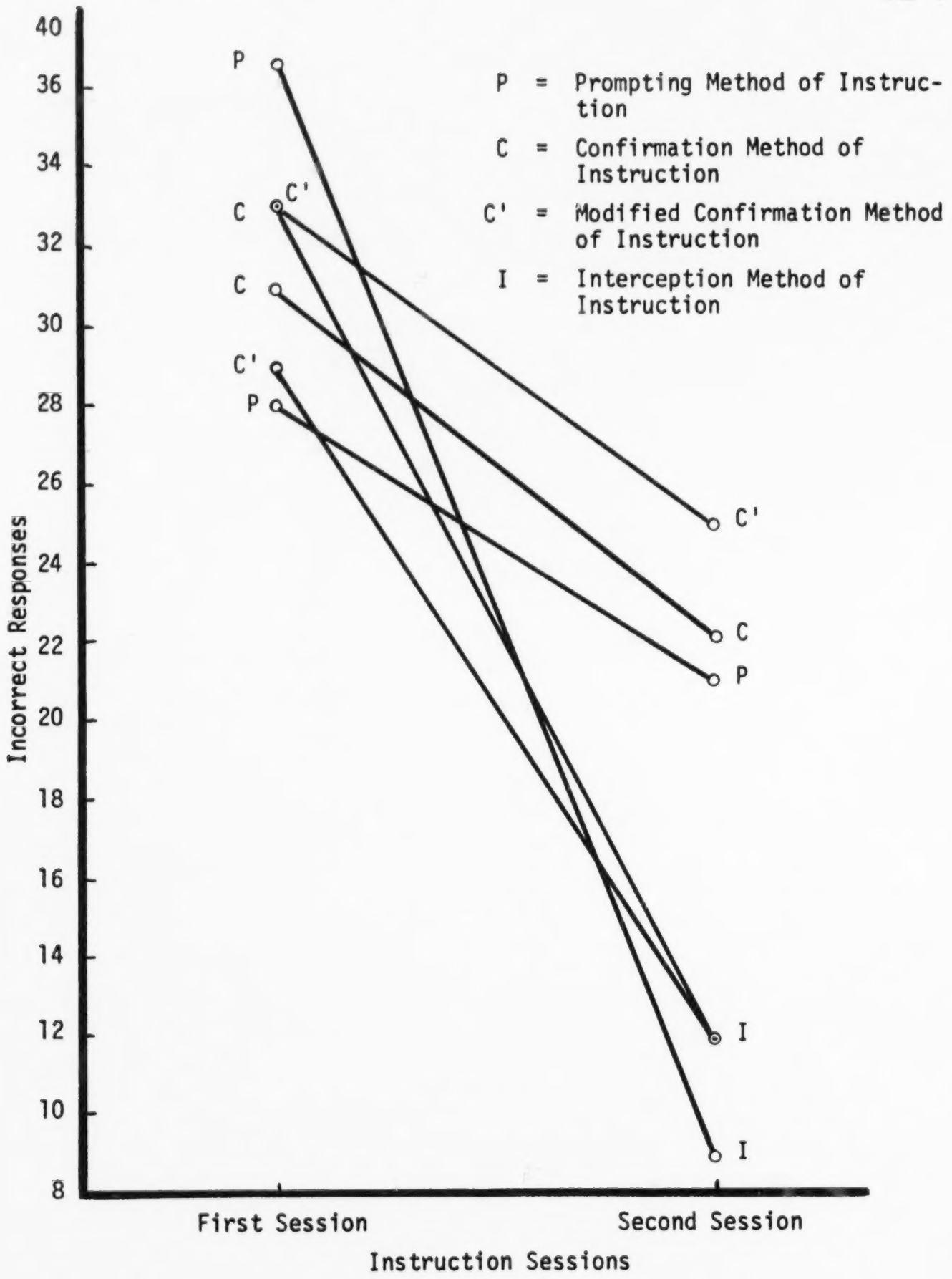


Fig. 11. Interactions between sequence of instruction methods and instruction sessions using the number of incorrect responses during acquisition as the dependent variable.

Table 7

Summary of Multiple Comparisons Computed by Scheffe's S Method for the Second Instruction Session Using Number of Incorrect Responses During Acquisition as the Dependent Variable

	Instructional Method						Critical Difference	Probability
	I_P	I_C	$I_{C'}$	P_P	C_C	$C'_{C'}$		
N	20	19	18	20	17	20		
Mean	9.3	12.0	12.8	20.9	22.5	25.3		
Comp.	-1/3	-1/3	-1/3	+1	0	0	0.95	< .05
	-1/3	-1/3	-1/3	0	+1	0	0.95	< .05
	-1/3	-1/3	-1/3	0	0	+1	0.95	< .05
	0	0	0	+1	-1	0	1.16	N.S.
	0	0	0	+1	0	-1	1.16	N.S.
	0	0	0	0	+1	-1	1.16	N.S.

Note: Subscript indicates method of instruction used during first instruction session.

criterion. The differences between the mean number of errors made by subjects assigned to any of the remaining three instruction methods reached the .05 level of significance. No other significant differences between means were obtained.

In summary, analysis of the results describing the subjects' performance during the second instruction session, the session during which all of the instruction methods were employed, using three dependent variables, did not support the expectation that the interception method would increase the efficiency of the learning process. Subjects assigned to the interception method required more time to reach

criterion than subjects assigned to the remaining three instruction methods. Subjects assigned to the prompting method required the least time to reach criterion. Although no differences in the number of correct responses made by the subjects assigned to each of the instruction methods was expected, subjects assigned to the interception method made more correct responses before reaching criterion than subjects assigned to either the prompting or modified confirmation method. The expectation that subjects assigned to the interception method would make fewer incorrect responses than subjects assigned to either the prompting, confirmation, or modified confirmation method was supported.

14-Day Retention

Each of the 120 subjects was administered two retention tests. The first retention test was administered approximately seven days after the completion of the second session. At least five days and not more than nine days elapsed between experimental sessions. Only data related to the second experimental session were analyzed since it was during this session that the interception method was employed. Separate analyses were computed for each of the two groups of subjects based on the set of stimuli administered at the second session.

An analysis of variance procedure for repeated measures was used to analyze the data obtained from those subjects who learned the responses to the A set of stimuli during the second experimental session. The data supported the homogeneity of variance assumption required by the analysis of variance procedure. No interactions or treatment effects reached the .05 level of significance indicating that the method of instruction employed during the acquisition stage of the

experiment did not affect the number of stimuli correctly identified seven or 14 days following acquisition. The finding was in opposition to the expectation that the method of instruction would affect retention.

An analysis of variance procedure was used to analyze the retention scores obtained from the subjects who learned the B set of stimuli during the second experimental session. The homogeneity of variance assumption was not violated. A significant result ($P < .05$), due to the method of instruction was obtained. Scheffe's S method for complex comparisons was used to determine the nature of the main treatment effect. The results are shown in Table 8. Subjects who learned the stimuli using the prompting method correctly identified a fewer number of the stimuli than those subjects taught the correct names of the stimuli by the confirmation method. The result was significant at the .05 level and opposite to the expected direction.

28-Day Retention

A total of 28 of the 60 subjects who learned the A set of stimuli during the second experimental session were available for two additional retention tests administered approximately 21 and 28 days following acquisition of the A set of stimuli. An analysis of variance procedure using data obtained from 28 subjects at four retention intervals was calculated. Bartlett's test for homogeneity of variance was non-significant. The method of instruction used during acquisition was shown to affect the number of responses correctly recalled. The result was significant beyond the .05 level. Scheffe's S method of multiple

Table 8

Summary of Multiple Comparisons Computed by Scheffe's S Method for the Sequence-of-Instruction-Methods Treatment Effect Using the Number of Correct Responses Obtained at Two Seven-Day Intervals to Stimulus Set B as the Dependent Variable

	Instructional Method						Critical Difference	Probability
	I_P	I_C	$I_{C'}$	P_P	C_C	$C'_{C'}$		
N	20	20	20	20	20	20		
Mean	10.15	10.30	10.35	7.60	11.85	11.30		
Comp.	-1/3	-1/3	-1/3	+1	0	0	2.32	N.S.
	-1/3	-1/3	-1/3	0	+1	0	2.32	N.S.
	-1/3	-1/3	-1/3	0	0	+1	2.32	N.S.
	0	0	0	-1	+1	0	2.32	< .05
	0	0	0	-1	0	+1	2.32	N.S.
	0	0	0	0	-1	+1	2.32	N.S.

Note: Subscript indicates method of instruction used during first instruction session with stimulus set A.

comparisons failed to detect significant differences between the means obtained from each method of instruction. The failure may be attributed to the conservativeness of Scheffe's S method.

A less conservative method of evaluating complex comparisons, the multiple-t procedure (Kirk, 1968) was used to analyze the comparisons. The results are shown in Table 9. Those subjects who learned the A set of stimuli by the interception method correctly recalled fewer responses than subjects who were taught the correct responses to the stimuli by either the prompting, confirmation, or modified confirmation

method. Subjects assigned to the interception method recalled an average of 9.5 correct stimulus-response associations. Subjects assigned to the prompting, confirmation, and modified confirmation methods recalled an average of 12.4 correct stimulus-response associations. This result was in opposition to the anticipated result. No significant differences were observed in the number of correct responses on the four retention tests made by subjects who learned the correct stimulus-response pairs by either the prompting, confirmation, or modified confirmation method.

Table 9

Summary of Multiple Comparisons Computed by Multiple-T Method for the Sequence-of-Instruction-Methods Treatment Effect Using the Number of Correct Responses Obtained at Four Seven-Day Intervals to Stimulus Set A as the Dependent Variable

	Instructional Method						Critical Difference	Probability
	I_C	I_C	$I_{C'}$	P_P	C_C	$C'_{C'}$		
N	20	20	20	20	20	20		
Mean	10.54	8.68	9.29	12.21	12.67	12.30		
Comp.	-1/3	-1/3	-1/3	+1	0	0	2.25	< .05
	-1/3	-1/3	-1/3	0	+1	0	2.25	< .05
	-1/3	-1/3	-1/3	0	0	+1	2.41	< .05
	0	0	0	-1	+1	0	2.70	N.S.
	0	0	0	-1	0	+1	2.83	N.S.
	0	0	0	0	-1	+1	2.83	N.S.

Note: Subscript indicates method of instruction used during first instruction session with stimulus set B.

A total of 26 of the 60 subjects who learned the correct stimulus-response associations to the B set of stimuli during the second experimental session were administered a total of four retention tests. The retention tests were administered approximately seven days apart. No non-chance differences were related to the retention interval or the instruction methods.

In summary, the results of the analyses of the number of stimuli for which correct responses were given are inconclusive. In general, the method of instruction used for the acquisition of the stimulus-response pairs did not affect retention. The conclusion is in opposition to the expectation that subjects who learned the stimulus-response pairs by the interception method would make a greater number of correct responses than subjects who learned the stimulus-response pairs by either the prompting, confirmation, or modified confirmation method. The data do not support the expectation that subjects who learned the stimulus-response associations by the prompting method would make a greater number of correct responses than subjects assigned to the confirmation method, but fewer correct responses than the subjects assigned to the modified confirmation method.

CHAPTER VI

DISCUSSION

The interception method of instruction performed the task for which it was designed. Subjects who learned the stimulus-response associations by the interception method made fewer overt incorrect responses than subjects who learned the stimulus-response associations by the prompting, confirmation, or modified confirmation method. However, the interception method did not prove to be the most efficient method of instruction. Subjects assigned to the interception method required more time to reach criterion and required more correct responses before reaching criterion than subjects assigned to either of the prompting, confirmation, or modified confirmation methods. The additional time spent at the task by the subjects assigned to the interception method did not result in substantial gains in retention. None of the instruction methods resulted in substantial gains in retention.

Failure of the data to support the efficacy of the interception method is not to be taken as a failure of computer-assisted instruction in the teaching of beginning shorthand. The most practical conclusion of this study is that computer-assisted instruction succeeded in teaching the correct responses to the beginning shorthand alphabet. Subjects who learned the names of the 30 beginning shorthand symbols by the prompting or confirmation method required an average of 30 minutes a day for two days to reach the criterion of 10 consecutive errorless trials. Approximately 75 per cent retention was obtained over a four week period without additional instruction.

Computer-assisted instruction also guaranteed that each subject match the established criterion before progressing to advanced study. Subjects required from 17 to 28 minutes to match the established criterion. Shorthand teachers are urged to utilize the many advantages gained by the use of computer-assisted instruction for the teaching of beginning shorthand.

Additional research is needed to evaluate and improve the new instructional strategies made possible by the application of the computer to educational tasks. The study of the interception method of instruction, made possible by the use of the computer, suggests additional areas for research. Several explanations, both practical and theoretical, can be hypothesized to account for the inefficiency of the interception method.

The interception method may not have applied Guthrie's theory of learning as he originally conceived it. The interception method was primarily based on the extensions made to Guthrie's theory by Voeks (1950) and Sheffield (1961) and the application of Guthrie's theory to classroom teaching made by Bugleski (1964). Guthrie based his theory on observable behaviors. Muscular movements or glandular secretions made in response to a stimulus were the dependent variables. The interception method tested in this experiment was based in part on Guthrie's theory of learning and was concerned with the prevention of the occurrence of overt responses. Guthrie would probably argue that the covert responses undetected by the computer program were the responses conditioned to the stimulus. The interception method was designed to prevent the occurrence of overt responses, not covert responses. In this light, the interception method of instruction failed to establish the

conditions necessary to Guthrie's theory of learning. The subject may have determined the answer he was going to type, and therefore actually have given a sub-verbal response, within the period of time allotted for a response. Only the actual typing of the response was intercepted by the program. Occurrences of this nature were not prevented from happening.

Observations of the subjects working at the student station also indicated that subjects typed their responses after expiration of the time allotted for a response. The subjects went through the motions of typing and "entering" their responses even though their typed responses did not appear on the face of the cathode ray tube and their responses were not recognized by the computer. Two inadequacies of the system, the inability to separate typing and "entering" time from response latency, and the inability to prevent subjects from pressing keys on the keyboard of the student station when a response is not required, may have prevented this study from being an adequate test of Guthrie's theory.

Observation of the subjects assigned to the interception method provided an alternate hypothesis to account for the failure of the interception method. Each subject reacted in a different manner to the occurrence of an error or the notification given by the computer program that the subject's hesitancy to respond was classified as an incorrect response. Many of the subjects became so upset and irritated that they failed to respond, or gave an incorrect response upon the next request for a response. Their behavior only compounded the number of additional correct responses required before the criterion was matched. An incorrect response during the final test required a minimum of nine

additional correct responses prior to the administration of the final test. One subject, not included in the analysis, failed to complete the second instruction session after repeatedly approaching criterion, but making an error on the final trial. Each actual error made by the subject was accompanied by several predicted errors.

Subjective data of this nature suggested the possibility that the interception method failed to increase the efficiency of the learning process because of the heterogeneity of subjects' ability to act under various levels of anxiety or tension. It was evident that the interception method was perceived as a high anxiety situation by a number of the subjects suggesting the possibility of an aptitude-treatment interaction. Perhaps the interception method was effective only for those subjects who reacted favorably to the stress created by the unusual method of instruction.

Several additional areas of concern must be examined before the interception method could be utilized in the construction of computer-assisted instruction courses. Although this study succeeded in creating two equated sets of stimuli, more efficient methods of determining an individual's correct-response latency must be created and tested. Perhaps it is not necessary to determine in advance each individual's correct-response latency. Instead, each subject's correct-response latency could be determined during the time the subject is working at the student station. During the first trial of the experiment, an arbitrary value might be chosen to represent the subject's correct-response latency. An incorrect response by the subject would indicate that the approximation was too high, and an appropriate modification could be made before the start of the next trial. Each incorrect

response could be followed by a decrease in the amount of time allotted for a correct response. Correct responses would not necessitate modification of the correct-response latency. Intercepted responses would necessitate an increase in the amount of time allotted for a correct response in order to determine whether or not the intercepted response was a potentially incorrect response. If the intercepted response was potentially incorrect, as shown by the occurrence of an incorrect response after the correct-response latency had been lengthened, the correct-response latency would return to its earlier level, only to be modified following the occurrence of an incorrect response with a latency less than the correct-response latency. However, if correct responses continue to occur after the correct-response latency had been lengthened, an error in prediction would be indicated and the correct-response latency lengthened to correct the error.

Implementation of the method of determining correct-response latencies just described would have several advantages over the method utilized in this study. Ten consecutive errorless trials would not be required to obtain correct-response latency data. The high degree of overlearning required by the study may have equalized any gains in retention caused by the four methods of instruction. Stolurow (1963) and Cain (1967) showed that gains in retention were related to the degree of overlearning. The individual's correct-response latency would be determined throughout the course of the experiment and continually modified to reflect changes in the individual.

An additional advantage gained by the implementation of the method just described for determining a subject's correct-response latency is that the method is dynamic and occurs in real time rather

than static and based on the subject's past performance. The dynamic nature of the proposed method might permit the model to function more effectively during the trials prior to and immediately following the trial of last error--the trials characterized by the high degree of variability present in the data. A higher correct-response latency would be employed during the early trials of the experiment than the correct-response latency used during the later trials, after the subject's correct-response latency had stabilized. Additional research is needed to determine the merits of the proposed dynamic method of determining a subject's correct-response latency.

Additional research is also needed to determine the action to be taken following the prediction of an incorrect response. The presentation of the correct response used in this study is only one of the many strategies that might be employed. The prediction of an incorrect response might be followed by a clue designed to lead the subject toward the correct response. Or the subject might be presented with a multiple-choice question with one of the response alternatives being the correct response. A strategy of this type might also lead the subject to the correct response without actually showing the correct response to the subject. A third alternative, better suited to stimuli of a different nature, would be to branch the subject to remedial instruction designed to clarify the misconception by presenting the instruction in a different format. A strategy of this nature would be more appropriate for instruction presented in the tutorial mode rather than the drill and practice mode employed in this study.

Several explanations have been proposed in this chapter to account for the inefficiency of the interception method in improving the learning process. A number of the explanations were relative to the theoretical framework of the model while others were directed toward the practical problem of implementing a new teaching strategy through the use of computer-assisted instruction. Additional research is needed to test the validity of each of the explanations. Until such research is completed, designers of curricula for implementation on computer-assisted instruction systems would be well advised not to attempt to prevent the occurrence of incorrect responses.

CHAPTER VII

SUMMARY

The introduction of the computer to educational tasks has resulted in a variety of new instructional strategies and instructional formats. The computer's ability to make quick decisions based on vast amounts of data has made it possible to provide each student with an instructional sequence based on the student's own past performance. Data obtained from an earlier instructional session can be used to determine the sequence of events to take place during any succeeding session. During each session, continual monitoring of a student's performance permits the immediate detection of misunderstandings or wrong associations. Upon detection of such a condition, the computer can be programed to alter the instructional format to clarify the minunderstandings. This study was designed to test a method of instruction which used data obtained from a student's past performance to predict and prevent the occurrence of incorrect responses and by implication, wrong associations. The model of instruction developed and tested in this study was implemented in a computer-assisted instruction setting.

The model was developed for the teaching of beginning shorthand through the use of computer-assisted instruction. The learning theory of E. R. Guthrie (1935, 1942), the extensions made to Guthrie's learning theory by Voeks (1950) and Sheffield (1961), the applications of Guthrie's theory by Bugleski (1964) and the research literature centering around retroactive and proactive inhibition formed the basis of the model. The model was based on the proposition that incorrect responses decrease the efficiency of the learning process. The response

which last occurred in association with the stimulus is the response that will most likely be given upon the next presentation of the stimulus. If the last response was an incorrect response, conditions would have to be created for an additional presentation of the stimulus and the occurrence of an alternate response. The prevention of incorrect responses and their subsequent conditioning to the stimulus would eliminate the need for additional presentations of the stimulus and increase the efficiency of the learning process. It was hypothesized that an individual's response latency could be used to predict the occurrence of an incorrect response.

Research literature defining the attributes of an individual's response latency was not abundant. The majority of the research literature examined the average response latency obtained from grouped data rather than response latency data related to an individual learner. The literature suggested that response latency data were relatively unstable, but that a trend existed whereby response latencies of incorrect responses were, on the average, longer than response latencies of correct responses. The assumption was made for the purposes of the model developed in this study, that the unreliability of the response latency measure was caused by high inter-subject variability which could be eliminated by the use of response latencies on an individual basis. Response latency data for correct and incorrect responses were analyzed for each individual rather than across a group of subjects.

Based on this assumption and on the premise that incorrect-response latencies are longer than correct-response latencies for any given individual, it was hypothesized that response latency data could be used to predict the occurrence of incorrect responses. Any response

not completed within the time period associated with a correct response was predicted to be an incorrect response. Upon the prediction of an incorrect response, action was taken to "intercept" and prevent the occurrence of the response. The "interception" method was the result of the model developed for the teaching of beginning shorthand through the use of computer-assisted instruction.

Implementation of the model was based on the assumption that data describing an individual's correct-response latency were already available. As used in this study the term response latency was defined as the period of time which elapsed from the point the subject was instructed to make a response to the point at which the subject signaled the completion of his response. The term "response latency" included the time required by the subject to type his response. An individual's correct-response latency was dependent in part upon the number of characters contained in the response. A pre-experiment was conducted prior to testing of the model, to create two mutually exclusive sets of stimuli, each consisting of 15 basic shorthand symbols. The two sets of stimuli were matched on the basis of each symbol's mean median correct-response latency. Each stimulus in set A was paired with a stimulus in set B. Both members of the pair had similar mean median correct-response latencies. Either set of stimuli could be used to collect data to define a median correct-response latency for each stimulus in the unused set of stimuli.

A total of 120 subjects were used to test the model. Two experimental sessions were required for the acquisition of the stimuli. A different set of stimuli were used on each day, although the order of presentation of the stimuli sets was rotated. The stimuli set used

during the first experimental session was used to obtain data to define each subject's median correct-response latency for each stimulus. Three methods of instruction were used during the first experimental session. Subjects randomly assigned to the prompting or confirmation method were administered a combination of testing and training trials. A training trial followed each testing trial on which errors were made. During a training trial, subjects assigned to the prompting method were shown both the stimulus and response and asked to type the correct response. Subjects assigned to the confirmation method were shown only the stimulus and asked to type the correct response. Following the subject's response, the correct response was displayed for the subject. During testing trials, the correct response was never shown to the subject. A median latency was calculated for each subject for each stimulus based on the last nine correct responses which occurred during testing trials. These data were stored in the computer for use during the second experimental session.

The third method of instruction was a modification of the confirmation method. Each stimulus was shown to the subject and he was asked to type the correct response. Follow each response, the correct response was displayed for 10 seconds. A median latency was calculated for each subject for each stimulus based on the last nine correct responses given for each stimulus. These data were also stored for use during the second experimental session.

One-half of the subjects served as a control group during the second experimental session. These subjects learned the names of the second set of shorthand symbols by the same methods used during the

first experimental session. Those subjects randomly assigned to the prompting method during the first session were also assigned to the prompting method during the second session. No attempts were made to predict or prevent incorrect responses.

The interception method was used for the remaining subjects. Each subject's response latencies were monitored and compared to the median correct-response latency stored in the computer for the comparable stimulus. If the subject's response latency exceeded the median correct-response latency by one second, the request for a response was erased from the screen and a prompt, consisting of the correct response was displayed to the subject for 10 seconds before proceeding to the next stimulus. Every response with a latency less than the corresponding stimulus' median correct-response latency plus one second, was confirmed by a display of the correct response for 10 seconds. This procedure was followed until each stimulus was correctly identified on 10 consecutive trials.

Analysis of the data obtained during the second acquisition session, indicated that subjects assigned to the interception method required more time to reach criterion and made a greater number of correct responses before obtaining criterion than subjects assigned to the prompting, confirmation, or modified confirmation method. Subjects assigned to the modified confirmation method also required more time to reach criterion than subjects assigned to the prompting or confirmation method. As anticipated, fewer incorrect responses were made by subjects assigned to the interception method than subjects assigned to one of the other three methods of instruction.

Results of the analysis of the number of correct responses recalled over four one-week intervals were inconsistent. In general, the null hypothesis that the method of instruction used for the acquisition of the correct responses would have no effect on the number of correct responses recalled following 7, 14, 21, and 28 days after the acquisition of the correct responses was retained.

The interception method of instruction served the purpose for which it was designed. Subjects learning the correct responses to the stimuli by the interception method made fewer incorrect responses than subjects assigned to the prompting, confirmation, or modified confirmation method. However, the interception method did not increase the efficiency of the learning process.

The use of computer-assisted instruction was successful in teaching students to identify the shorthand symbols contained in the beginning shorthand alphabet. Subjects assigned to the prompting or confirmation method were able to correctly identify each symbol following 30 minutes of instruction on two successive days. Approximately 75 per cent retention was maintained over a four-week period without additional instruction. The use of computer-assisted instruction also guaranteed that each student matched the established criterion before progressing to additional work. Each student received the exact amount of instruction he needed in order to match the criterion. Additional research is needed in the development and evaluation of the many new instructional strategies made available by the application of the computer to educational tasks.

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APPENDIX

Table 10

Analysis of Variance Summary Table Using Time-to-Reach-Criterion During Acquisition as the Dependent Variable

Source	df	Sums of Squares	Mean Square	F
Between Subjects				
Sequence of Instruction Methods	5	29474.2	5894.8	16.7
Order of Stimulus Set Presentation	1	112.1	112.1	< 1.0
Sequence x Order	5	518.9	103.8	< 1.0
Error	108	38105.5	352.8	
Within Subjects				
Instruction Sessions	1	1179.3	1179.3	13.0
Sequence x Sessions	5	17836.6	3567.3	39.4
Order x Sessions	1	77.1	77.1	< 1.0
Sequence x Order x Sessions	5	533.2	106.6	1.2
Error	108	9789.9	90.6	

Table 11

Analysis of Variance Summary Table for Simple Effects During the Second Instruction Session Using Time-to-Reach-Criterion as the Dependent Variable

Source	df	Sums of Squares	Mean Square	F
Sequence of Instruction Methods	5	33448.2	6689.6	29.5
Order of Stimulus Set Presentation	1	1.6	1.6	< 1.0
Sequence x Order	5	644.4	128.9	< 1.0
Error	108	24468.6	226.6	

Table 12

Analysis of Variance Summary Table Using Number of Correct Responses During Acquisition as the Dependent Variable

Source	df	Sums of Squares	Mean Square	F
Between Subjects				
Sequence of Instruction Methods	5	28953.5	5790.7	3.8
Order of Stimulus Set Presentation	1	8.8	8.8	< 1.0
Sequence x Order	5	3802.1	760.4	< 1.0
Error	102	155500.0	1524.5	
Within Subjects				
Instruction Sessions	1	10374.8	10374.8	12.4
Sequence x Sessions	5	34108.8	6821.8	8.1
Order x Sessions	1	22.1	22.1	< 1.0
Sequence x Order x Sessions	5	2701.7	540.3	< 1.0
Error	102	85589.6	839.1	

Table 13

Analysis of Variance Summary Table for Simple Effects During the Second Instruction Session Using Number of Correct Responses During Acquisition as the Dependent Variable

Source	df	Sums of Squares	Mean Square	F
Sequence of Instruction Methods	5	61651.0	12330.2	6.2
Order of Stimulus Set Presentation	1	23.7	23.7	< 1.0
Sequence x Order	5	3905.2	781.1	< 1.0
Error	102	203213.0	1992.3	

Table 14

Analysis of Variance Summary Table Using Number of Incorrect Responses During Acquisition as the Dependent Variable

Source	df	Sums of Squares	Mean Square	F
Between Subjects				
Sequence of Instruction Methods	5	1840.4	368.0	2.1
Order of Stimulus Set Presentation	1	390.1	390.1	2.2
Sequence x Order	5	1592.5	318.5	1.8
Error	102	17772.0	174.2	
Within Subjects				
Instruction Sessions	1	12990.5	12990.5	115.4
Sequence x Sessions	5	3308.8	661.5	5.9
Order x Sessions	1	51.9	51.9	< 1.0
Sequence x Order x Sessions	5	785.8	157.1	1.4
Error	102	11480.4	112.1	

Table 15

Analysis of Variance Summary Table for Simple Effects During the Second Instruction Session Using Number of Incorrect Responses During Acquisition as the Dependent Variable

Source	df	Sums of Squares	Mean Square	F
Sequence of Instruction Methods	5	4192.9	838.6	10.1
Order of Stimulus Set Presentation	1	78.4	78.4	< 1.0
Sequence x Order	5	359.9	72.0	< 1.0
Error	102	8435.5	82.7	

Table 16

Analysis of Variance Summary Table for Stimulus Set A Using Number of Correct Responses as the Dependent Variable

Source	df	Sums of Squares	Mean Square	F
Between Subjects				
Sequence of Instruction Methods	5	100.9	20.2	1.6
Error	54	661.1	12.2	
Within Subjects				
Retention Interval	1	2.1	2.1	1.4
Sequence x Interval	5	2.2	0.4	< 1.0
Error	54	83.7	1.6	

Table 17

Analysis of Variance Summary Table for Stimulus Set B Using Number of Correct Responses as the Dependent Variable

Source	df	Sums of Squares	Mean Square	F
Between Subjects				
Sequence of Instruction Methods	5	214.1	42.8	3.2
Error	54	729.3	13.5	
Within Subjects				
Retention Interval	1	1.9	1.9	< 1.0
Sequence x Interval	5	3.7	0.7	< 1.0
Error	54	120.0	2.2	

Table 18

Analysis of Variance Summary Table for Stimulus Set A Using Number of Correct Responses as the Dependent Variable

Source	df	Sums of Squares	Mean Square	F
Between Subjects				
Sequence of Instruction Methods	5	295.9	59.2	2.9
Error	27	556.8	20.6	
Within Subjects				
Retention Interval	3	7.4	2.5	2.0
Sequence x Interval	15	8.3	0.6	< 1.0
Error	81	101.3	1.3	

Table 19

Analysis of Variance Summary Table for Stimulus Set B Using Number of Correct Responses as the Dependent Variable

Source	df	Sums of Squares	Mean Square	F
Between Subjects				
Sequence of Instruction Methods	5	148.3	29.7	1.0
Error	26	768.0	29.5	
Within Subjects				
Retention Interval	3	0.03	0.01	< 1.0
Sequence x Interval	15	42.7	2.8	1.1
Error	78	193.3	2.5	